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RADIATING ATOMS IN MAGNETIC FIELDS.*

BY

PROFESSOR PIETER ZEEMAN.

University of Amsterdam.

When I had the honor to be invited to deliver an address in Philadelphia at the centenary of The Franklin Institute, I immediately accepted this invitation for so memorable an occasion. I selected for my subject: "Radiating Atoms in Magnetic Fields," a chapter of physics which I follow with some interest.

A new epoch for spectroscopy was opened in 1882 by the work of H. A. Rowland, at Johns Hopkins University, Baltimore, by the invention of the concave grating. Rowland's great invention made it possible to make measurements on spectral lines one hundred times more accurate than those of his predecessors. All over the world the Rowland grating was introduced into physical laboratories, and photography made it possible to record permanently the varying aspects and shades of spectrum lines obtained under diverse circumstances.

In some directions the work of Rowland has been surpassed by Michelson. To him we owe the echelon-spectroscope and the interferometer. It is certainly most remarkable that by setting together a series of perfectly plain plates of equal thickness, which decrease in size by an equal amount, a grating is obtained of very high resolving power and giving spectra of very great inten-

* Address delivered Friday, September 19, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

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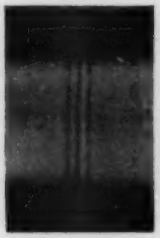
sity. The brilliancy of the images of the echelon-spectroscope makes it possible to ascertain at once that most spectrum lines are accompanied by fine, faint lines, usually indicated as satellites.

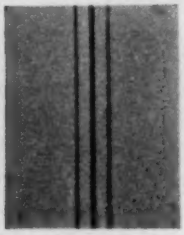
This fact and the simple structure of the red cadmium line was first discovered by means of another great invention of Michelson: The interferometer. This instrument is perhaps still more simple in principle than the echelon. A few perfectly plane glass plates are again the principal constituents and seem sufficient for the most beautiful discoveries.

The names of Rowland and Michelson are daily before the mind of the spectroscopist.

We cannot refrain from recording at this time the satisfaction

FIG. 1. FIG. 2.





felt by all physicists over the fact that Fabry and Perot found by their widely different interference method, in collaboration with Benoit, for the wave-length of the cadmium red line a value practically identical with that published by Michelson.

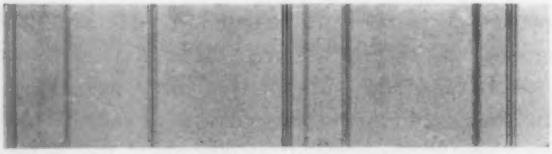
The great resolving power of the Rowland grating was of paramount significance in the discovery of the effect of a magnetic field on a radiating substance.

Between the poles of an electromagnet we place a flame, colored red with a lithium salt. We observe in a direction normal to the field and fix our attention on the red lithium line. As soon as the field is put on we see in place of the spectrum line three lines, a triplet (Fig. 1). We repeat the experiment with a zinc spark, or with an iron spark, the effect is much the same, the lines are narrower (Fig. 2). This figure is, in fact, one of my very early photographs, exhibiting not one line but a part of the spectrum. Observe the different degrees of separation of the different lines (Fig. 3).

The next figure illustrates the polarization of the decomposed spectrum line. The two yellow mercury lines, at a distance apart of between three and four times that of the yellow sodium lines, are separated into triplets (Fig. 4).

By means of a calcspar rhombohedron two images of the source are obtained, one consisting of horizontal, the other of vertical vibrations, or, more accurately expressed, one image is

FIG. 3.



due to vibrations parallel to the direction of the magnetic field, the other contains the vibrations perpendicular to the field. It is very remarkable that the polarization of the light is to complete, and that the effect is not hazy, but very definite.

These are the principal facts. We now go back to somewhat more than a quarter of a century ago. It is rather difficult to represent to one's self the state of science so long ago. For the present subject a review of those days was recently written in

FIG. 4.

a most charming manner by Prof. Kamerlingh Onnes. The theory of Lorentz had just appeared at that time in two fundamental papers, in which the attempt was made to reduce all electrical and optical phenomena to the configuration and motion of small electrically charged bodies, each with a definite mass, which were assumed to be present in all ponderable matter. The phenomenon of electrolysis had made the idea of positive and negative " ions " familiar to all physicists, and the idea of vibrat-

ing, charged particles present in a source of light was most attractive. These particles being electrified, when vibrating under "elastic" forces, were able to excite in the ether the electromagnetic vibrations which, according to Maxwell's theory, constitute light.

"Electrons" as such were unknown at the time. The sign of the charge of the vibrating particles and the ratio of their charge and mass were as yet undetected.

The influence of a magnetic field on spectrum lines, when first discovered, consisted in a broadening of the emission lines and of the absorption lines as well. It was an extremely happy circumstance that Lorentz's theory had been developed so far at the time that he could explain this effect and that he could predict under certain reserves polarization effects of the borders of the lines and even that doubling and tripling of the original lines ought to be observed. You have seen in the figures how splendidly these predictions were verified.

In communications to the Amsterdam Academy in May and October, 1897, presented by Kamerlingh Onnes, I was able to announce that the doublets and triplets predicted by Lorentz's theory had been made visible. The later observations were made with one of the cadmium lines and the means employed were only just sufficient to show the effects. The three elements, necessary for complete success in the magnetic resolution of spectrum lines, are: Narrow lines, great resolving power of the spectroscope, and strong magnetic fields. The history of the subject shows how rarely the desired combination of events took place. There is one fortunate circumstance I have not yet mentioned. The ratio of charge and mass of the vibrating particle was shown in my first experiments to be 10^7 c.g.s. units; and the sign of the charged particle was also made sure of, at the time when the values of e/m determined by J. J. Thomson and by Wiechert in their investigations of cathode-rays were made known. If the ratio for the vibrating particles in a flame should have been the same as that for the hydrogen ions in electrolysis, I fear that even Professor Michelson could not have discovered the change of period.

The simple triplet type of resolution was soon recognized to be not the only one.

The yellow sodium lines are a case in point. They are separ-

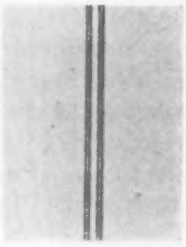
ated into four and six components, respectively (Fig. 5). Instead of three components there appear three groups of components,

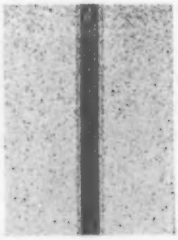
FIG. 5.

consisting of a variable number of constituents. I want to show a few instances of complex resolution.

Here is a calcium line 3969 (a quartet) (Fig. 6); here is another calcium line 3934 (a sextet) (Fig. 7). The next is a

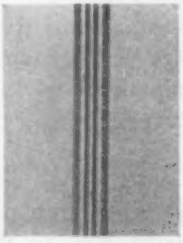
FIG. 6. FIG. 7.

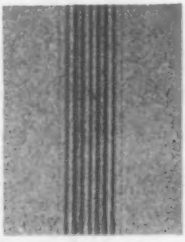




zinc line 4722, exhibiting a sextet of non-equidistant lines, also found with mercury 4359 (Fig. 8). And here we have the green mercury line 5461, which is resolved into a nonet of equidistant components of unequal but symmetrically distributed intensities

FIG. 8. FIG. 9.





(Fig. 9). The beauty of these magnetic resolutions is undeniable. There have been discovered some very important facts concerning the magnetic resolutions of those groups of lines in a spectrum which are closely allied and form spectrum series.

All the lines belonging to a *series* exhibit the same type of resolution. Not only is the pattern for the different lines the same in appearance, but if drawn to the scale of frequencies it is identical.

Moreover, there is a rule relating to the corresponding series of *different* elements. You remember the resolution of the two sodium lines (they are split up into a sextet and a quartet). Pairs of lines such as the sodium lines occur also in the spectra of copper, silver, aluminum, thallium, calcium, strontium, and barium. The behavior of all these doublets in the magnetic field is exactly like that of the sodium doublet. The patterns, if drawn on the true scale, can be superposed. The natural triplets, observed in the spectra of mercury, magnesium, strontium, zinc and cadmium, again have the same type of resolutions.

These important rules were first announced by Preston and next completely investigated by Runge and Paschen.

We owe to Runge a rule connecting the complicated resolutions with the most simple triplet resolutions of Lorentz's theory. In the diagram a summary of different types of magnetic patterns is given, illustrating the rule due to Runge (Fig. 10). Helium is resolved into a normal triplet. For sodium the components are at distances in simple relation with the normal triplet. Instead of one particular line of an element we might have taken, according to Preston's rule, any line of the series to which the line belongs on, even of any corresponding series of a different element.

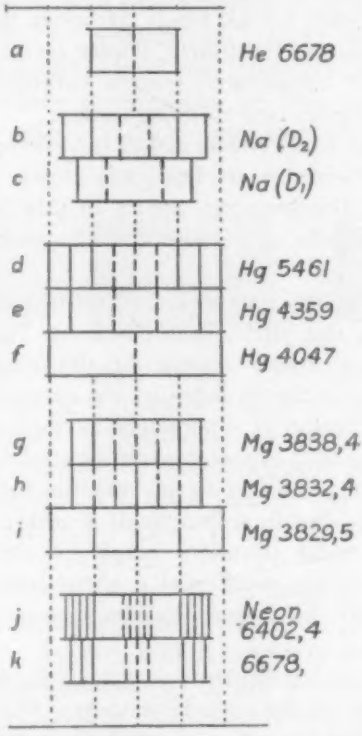
Next come mercury lines belonging to a natural triplet. The line indicated f is resolved into a triplet, but with a separation twice the normal one. The other lines exhibit resolution patterns which apparently are related most simply to the normal effect. Remarkably enough there are always three groups of lines corresponding to each of the three components of Lorentz's theory. What does the information concerning these complex resolutions mean?

Lorentz's simple theory cannot explain these complex patterns, or their relation to the series. We confidently look now to the idea of the atom which is due principally to the fundamental researches of Rutherford and to the Bohr theory of spectra. And there is no doubt that the applications of the quantum theory in the hands of Sommerfeld and Debye, recently completed by Bohr by the application of the correspondence prin-

ciple, are full of promise for the understanding of the magneto-optical phenomenon.

According to the Rutherford-Bohr theory of the atom there is at the centre of the atom a minute nucleus surrounded by swarms of electrons moving very swiftly in definite orbits, of which the position and character is determined by certain relations

FIG. 10.



of the quantum theory, and by certain quantum numbers, generally small integers. The spectrum line is emitted if the electron passes from one stable orbit of a certain energy to a second orbit of less energy. The magnetic resolution of the spectrum lines is due to the resolution of the stable orbits into several others, corresponding to different energy levels, which the series electron may occupy during the various stages of excitation of the atom.

The fundamental idea of Bohr's theory that each spectral line

is due to the transition between two of the stable states, or, otherwise expressed, that its frequency may be calculated as the difference of two terms, has been splendidly confirmed by the magnetic resolution of spectral lines.

Lande has given lately, guided by the ideas of the quantum theory, an admirable scheme which seems to cover all complex magnetic resolutions by simple formulæ.

This scheme permits one to predict the magnetic resolutions patterns quantitatively for all kinds of series lines not only for doublet series (example, sodium), triplet series (example, mercury), but also for complicated spectra exhibiting quintet series (chromium) and sextet series (manganese).

The study of all these effects makes it possible for us to examine in detail the behavior of the intra-atomic processes under magnetic forces. The quantum theory in this case demonstrates that only a few definite orientations of the atom are possible in the magnetic field.

How profoundly the magnetic field influences the atomic edifice follows from the effect discovered by Paschen and Back concerning the continuous change of the magnetic resolution pattern if we increase the strength of the magnetic field.

The rule of Preston is completely at fault under these circumstances. We should expect that the natural doublet of sodium 2853 would exhibit, according to the rule, the superposition of the D_1 and D_2 patterns, but in strong fields a nearly normal triplet is the result. The most beautiful result of the late Professor Voigt's magneto-optical work was a theoretical scheme for the behavior of lines of the sodium doublet type in fields of increasing strength.

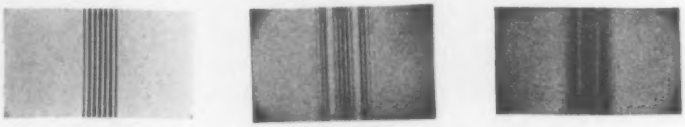
The properties of the elements vary with the atomic number in a manner described in the periodic system. We may expect that the magnetic resolutions will not exhibit a repetition as we proceed to higher atomic numbers, but that they will become more complicated. The magnetic resolutions may exhibit the type of hazy triplets, which, however, may finally turn out to be complex patterns. The analysis of these types is an object of great importance for the experimentalist.

Doctor Back, of Tubingen, has in recent years done much beautiful work in this direction, as is proved by his experimental analysis of the spectra of beryllium and manganese. In your

country many physicists have been working with much success on the magnetic analysis of the spectrum lines, among whom I mention in the first place King and Babcock. Among the younger investigators who are apparently entirely conversant with Lande's work, are to be cited Meggers, Kiess and Knudsen Kiess and Walters.

The necessity of combining high resolution, strong magnetic field, and narrow lines was already emphasized by me in my book on "Magnetic Optics" (Macmillan, 1913), but never was as much needed as in these days of new interest in spectrum analysis. I want to show three photographs of zinc lines taken in my laboratory, made with a vacuum oscillator of a type somewhat

FIG. 11. FIG. 12. FIG. 13.



different from Doctor Back's model. This method, initiated by Fabry and Perot, has been recently much developed and improved upon by Doctor Back. The components are very narrow, especially the ends of the lines. This photograph we may somewhat improve upon by covering a small part of our Rowland grating which has faulty ruling. Fig. 11 gives the nonet of zinc again under the improved conditions.

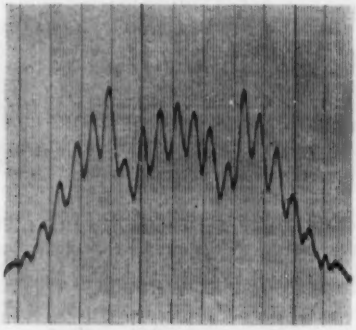
That we are now ready for further progress I can show you by some other photographs made in Amsterdam. The first relates to a chromium line (4290) with fifteen components (Fig. 12). The next one is a chromium line (4254) which is resolved by the magnetic field into not less than twenty-one components (Fig. 13). In order to spare you the difficulty of counting them, I have made by means of the thermo-electric photometer a photogram showing the intensity distribution of the resolved line (Fig. 14). There are really twenty-one components. A new feature of this photogram is the system of fine vertical lines. Their distance corresponds to 0.02 mm. in the original photograph and they have been introduced in order to eliminate the often troublesome error in the coupling between the revolving drum and the screw moving the photographic plate.

The part of the spectrum involved is only about 1 Ångström unit or one-sixth of the distance apart of the yellow sodium lines.

Our last photogram, exhibiting the photographic intensity of the different components of magnetically resolved lines, induces me to say a few words about the importance of accurate intensity measurements of spectral lines. Such measurements are as valuable as wave-length determinations. The ratio of intensities of multiplet lines gives very precious data for the quantum theory of the atomic model.

The measurements of Doctor Ornstein and his collaborators

FIG. 14.



at the Utrecht Laboratory have revealed a simple relation between intensities of multiplets and the numbers defining the spectrum. This relation may be applied to the magnetic components as well.

In the disentangling of the extremely complex spectrum of iron, an achievement due to the coöperation of physicists of different countries, the work of Babcock and King on the magnetic resolution of iron lines has been one of the methods to which the ultimate success was due.

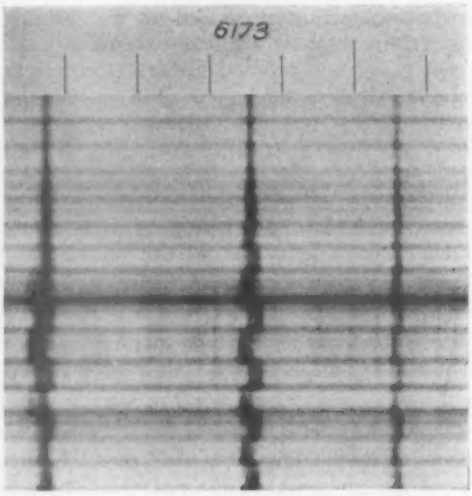
One of the spectra which merits to be investigated with some care is the spectrum of scandium. It belongs to the rare earths and according to Bohr it is the first of a group of elements where the conditions of binding of electrons are essentially different from those existing in previous periods of the periodic system. The scandium spectrum has been lately investigated in the magnetic field, I think for the first time, in the Amsterdam laboratory. Mr. Goudsmit and myself have come to the conclusion that the

resolutions predicted from Lande's rules and the observed ones agree exactly in most cases, but not so in other ones.

An immense amount of work remains to be done. May the splendid opportunities offered by the Bartol Research Foundation also be used in connection with the problems now under review.

I come now to the end of my address, but there is one point which I cannot refrain from touching on now that I have the pleasure of lecturing in America. I refer to the splendid

FIG. 15.



discovery made in 1908 by Dr. George Ellery Hale. Doctor Hale was able to show that the unique characteristics of the action of a magnetic field on spectral lines are present in the light of sun-spots, and to prove, after many searching trials, that in all sun-spots examined magnetic fields exist.

The iron triplet 6173, as photographed in a sun-spot with the 75-foot spectrograph of the 150-foot telescope and in the second order spectrum, is shown in Fig. 15, for which I am indebted to Doctor Hale.

By means of a special polarizing device the oppositely circularly polarized components of the magnetized spectrum lines are alternately extinguished. The central component is present because we do not look exactly along the lines of force.

The discovery of the magnetic fields in sun-spots was supplemented in 1912 by a new discovery relating to the general magnetic field of the sun, followed by the discovery by Doctor Hale and his associates of the extraordinary law of solar storms.

I suppose that most of you are quite familiar with this wonderful work, but I felt it as a duty and a pleasure here to refer to it, however briefly.

A Piezo-electric Oscillograph. C. E. WYNN-WILLIAMS. (*Phil. Mag.*, Feb., 1925.)—" The converse piezo-electrical phenomenon consists of the mechanical strain produced in a crystal when suitably electrified. This strain may be a linear extension or contraction, as in the case of quartz, or a combined linear and torsional effect as in the case of Rochelle salt crystals."

Quartz was first tried, but without success, since a slab of this crystal with the dimensions 5 cm. × 2 cm. × 0.3 cm. clamped at one end changed in length by only one-half the wave-length of sodium light, when a difference of potential of 10,000 volts was applied between the faces of the slab. " In passing, it is interesting to note that audible 'clicks' were heard from the quartz on charging and discharging the plates from the 200-volt mains. Assuming a linear voltage-displacement relation, it will be seen that the movement of the free end is only 5.897×10^{-7} cm."

Recourse was then had to crystals of Rochelle salt, about which considerable piezo-electric information is available, thanks to the work of Nicolson and of Valasek. Much experimenting was done with methods of growing crystals of size. " On the whole, crystals 2 to 4 cm. square were the largest which could be grown satisfactorily." A crystal 2.5 cm. square by 1 cm. thick received a girdle of tin-foil for one electrode and caps of the same material on its two ends, which, joined together, formed the other electrode. To the top of the crystal was attached an arm of aluminum. When a voltage was set up between the electrodes the crystal twisted a trifle and the arm turned a mirror. For 200 volts the torsion amounted to only 10^{-4} radian. To use the device as an oscillograph the trace of the light reflected from the mirror was photographed, while to the electrodes was joined the potential difference of which the variation is to be investigated. Certain advantages show themselves with such an oscillograph, *viz.*, " (1) high voltages are not required for operation as is the case in some electrostatic oscillographs. (2) The moving system does not require oil immersion. (3) Owing to its high resistance and impedance, the instrument is practically electrostatic. (4) The instrument has very low capacity. (5) The adjustment is not difficult. (6) The instrument is compact, of simple construction, and of low cost." A drawback is that it is suitable for low-frequency work only. G. F. S.

UNUSUAL PROBLEMS IN DESIGN AND CONSTRUCTION OF LARGE BRIDGES.*

BY

RALPH MODJESKI, D.ENG.

Member of the Institute.

THE engineer who designs and builds large bridges is often confronted by problems which are beyond the contents of text-books and which he must solve out of his own ingenuity and resourcefulness. The intimate history of the construction of almost every large bridge contains such unusual problems. They occur in every phase of the work, from location and design, on through all work of building, sometimes seemingly unimportant, at other times becoming the fundamental point of the whole project.

The location of a bridge is often indicated by existing roads of access or by natural conditions which make any other crossing of the stream or gulch impracticable. Such is not always the case, however. The location of the bridge at Celilo, Oregon, over the Columbia River, for instance, presented an unusual problem. The Spokane, Portland and Seattle Railway occupies the north shore of the river. The Oregon Trunk Railway was then under construction through Des Chutes Canyon, along the river of that name which runs from the south and flows into Columbia River a short distance above the town of Celilo.

The bridge had to be constructed in a location as near the mouth of Des Chutes River as possible, so to provide the shortest haul to the junction with the S. P. and S. Ry., and at the same time in such way as to make the bridge structure as economical as possible. Just above Celilo the formation of the bed of the river is very unusual and interesting. The river narrows down to about 2700 feet from shore to shore at high water. (Fig. 1.) At low water the bed of the river consists of a number of basaltic islands separated by violently rushing water. The main channel near the Oregon shore is about 300 feet wide, while the other channels, which are quite numerous, vary in width and are quite narrow,

* Address delivered Thursday, September 18, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

FIG. 1.

FIG. 2.

Celilo Bridge. River bed during low and high water.

some of them drying up entirely during low water. (Fig. 2.) Once a year, at high water, all these islands are submerged. The number of islands and their irregularity furnished quite a study for the proper selection of the crossing and several trials had to

be made in the immediate vicinity before the final location was decided upon. Unfortunately, no favorable location could be found at this place which would enable the crossing of the main body of the river at right angles to the current at high water, and

FIG. 3.

Columbia River Bridge, Celilo, Oregon. One of the 230-foot spans being erected by the cantilever method.

therefore a slight skew had to be contended with. On the other hand, the location selected allowed an arrangement of the spans by which six of the through-spans between the main channel and the beginning of the Y could be made of equal length, each pier being placed on rock above ordinary low water. Therefore, the foundation problem was made quite easy. As a result, we have an unusual bridge, where all foundations of the river piers may be

seen and examined each year. To speak more correctly, the foundations have been built above low water by Nature and it only remained for the engineer to place the piers on them, thus saving all expensive foundation work. (Fig. 3.)

The manner of erecting this bridge was dictated by the impossibility of placing falsework in some of the channels. The bridge was therefore erected by the cantilever method. The first through-span near the Washington shore was erected on falsework, but

FIG. 4.

Columbia River Bridge, Celilo, Oregon. Main span, 340 feet long, being erected by cantilever method.

all the other spans, excepting the draw-span, six in number, were erected by cantilevering each span from the preceding one. (Fig. 4.) While this method required a little additional material in the end-panels of the bottom chord, it proved quite economical in the end.

The conditions which must be met in locating a bridge at the most satisfactory point are so diversified that practically every bridge presents a special problem for which no general theory can be applied. The location of the Delaware River Bridge, for instance, was determined only after an exhaustive study of all existing conditions. Among the matters carefully studied were: The intensity of traffic crossing the river on ferry boats; the posi-

tion of the centres of gravity of the origin and the destination of vehicular traffic on both sides of the river; the probable distribution of traffic at both ends of the bridge; the physical conditions as to width of river and depth of foundations; the cost of real estate and the construction cost of the bridge. As a result of these studies, the present location of the bridge, selected out of five possible locations, was decided upon and adopted.[1]

FIG. 5.

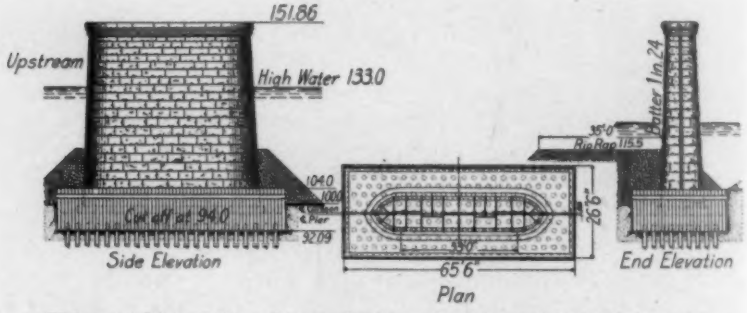
Delaware River Bridge. Open excavation caissons for anchorages.

Bridge pier foundations often present unusual problems. Perhaps the most difficult problem of that kind in the writer's experience were the foundations of the anchorage piers for the Delaware River Bridge just referred to. The rock was from 65 to 110 feet below the ground surface. Pneumatic caissons would have been possible, but too expensive. Two very large blocks of concrete, going down to rock, were needed for each anchorage to overcome not only the vertical lift, but also the horizontal pull of the huge cables. (Fig. 5.) These blocks, 40 ft. by 125 ft. by 63 ft.

[1] Detailed descriptions of these studies were published in the Preliminary Report of the Board of Engineers and in various technical papers.

to 68 ft. high on the Philadelphia side and 40 ft. by 140 ft. by 100.5 ft. to 104 ft. on the Camden side, were sunk by open excavation, without the use of compressed air. The material was excavated through wells provided in the concrete mass. Sinking was not begun until a height of 30 feet of concrete was built up and thoroughly set. Very heavy reinforcing with steel bars embedded in this 30-foot section took care of the bending due to possible unevenness of bearing on the soil. As the caisson sank, additional concrete was added on top of the block. After the excavation was completed and the caisson rested on rock, the wells were pumped out, cleaned and filled with concrete, making each large block a solid mass. It was quite difficult to conduct

FIG. 6.



Willamette River Bridge. Pier *A*, showing method of foundation and riprap fill.

the excavation in such a way that the enormous mass of concrete would sink gradually and without distortion of any kind.

A disturbing incident happened in connection with the foundations of one of the piers of the Willamette River Bridge near Portland, Oregon. All piers but one were founded on rock. The easterly pier, separated from the abutment by a 60-foot plate girder span, was located just back of a bulkhead forming the harbor line and acting as a retaining wall for a sand-fill. At that point the surface of the bed-rock was too deep for sinking pneumatic caissons for the full depth economically. The overlying material being pure sand and not subject to scour because of the bulkhead, a pile foundation was designed for this pier. A large cluster of piles was driven with an average penetration of 45 feet. (Fig. 6.) The piles were cut off below water. A special, shallow caisson was then constructed and sunk over the

piles by pneumatic process. The working chamber was filled with concrete, imbedding the tops of piles and resting on the sand. The pier was built on top of the caisson roof. Soon after it was completed, the railway company built a 50-foot embankment surrounding the abutment and extending with its toe to the pier in question. Before this embankment was finished, its great weight caused the pier to start settling. (Fig. 7.) A vertical settlement of 2½ inches was first noticed, as well as a deviation from the vertical toward the embankment. The obvious reason for this

FIG. 7.

Willamette River Bridge. East abutment, before the railway fill, which caused the settlement, was made.

settlement was that the foundation sand, all basaltic, was oversaturated with water, which, under the combined load of the pier and the embankment, began to squeeze out, letting the grains of sand come to a closer contact. The writer felt that as soon as the surplus water was squeezed out, the settling would stop. In order, however, to prevent further tilting of the pier, a train load of riprap was ordered at once to be deposited around its base on the channel side. This had the desired effect of arresting the pier's tendency to lean, but it kept on settling vertically for awhile until it had sunk about four inches in all. There has been no further settlement since then. The abutment surrounded by the new embankment settled also, of course, and stopped settling of its

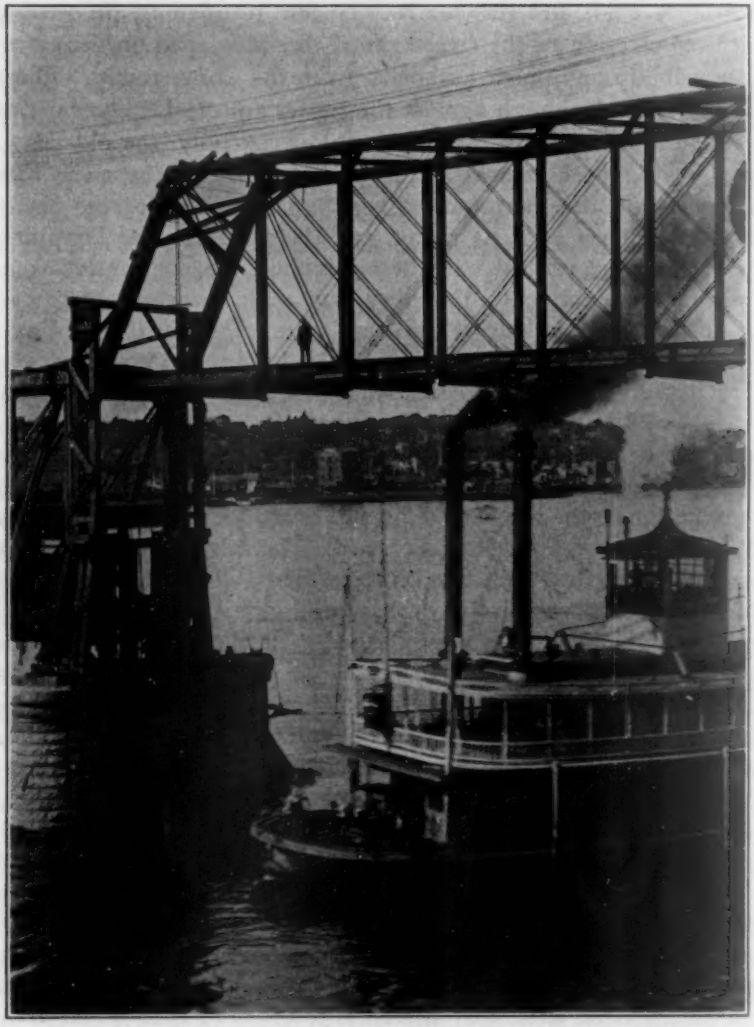
own accord, when sufficient surplus water was squeezed out of the sand under it.

The problem of rebuilding or strengthening bridges under traffic becomes more and more frequent. Almost every railroad has bridges which are inadequate to carry the modern loading and which at some time or other must be rebuilt or strengthened. Twenty or thirty years ago very few old structures were worth saving or utilizing in the reconstruction. To complicate the operations by trying to make use of the old material would have been often more expensive than building an entirely new bridge; though the masonry in many cases, of even very old bridges, has been found so well built that it could be utilized in a reconstructed bridge. Reconstructing or strengthening a bridge under traffic is always accompanied by difficulties, and almost every case presents a different problem.

At the very beginning of the writer's independent practice, he was placed in charge of the reconstruction of the Rock Island combined railroad and highway bridge, joining the City of Davenport on the Iowa shore with the island, which is occupied by the U. S. Arsenal. The problem there was to replace the old single-track iron bridge with a double-track structure, capable of carrying heavier motive power, without interruption to either railway or river traffic. The piers were found to be sound so that they needed only to be made somewhat longer to carry the new double-track spans. The upstream nose or cut water of each pier was originally built inclined at an angle of approximately 45 degrees. It was only necessary to take down a few courses of masonry and build a portion of the nose of the pier on a nearly vertical line to make the pier long enough for the double-track spans. The superstructure of the main bridge consisted of a 365-foot draw-span, two 258-foot fixed spans and three 216-foot fixed spans. The draw-span had to be erected in a way not to interfere with the traffic, and it was planned to do this work during the season of closed navigation. The erection of new fixed spans presented no difficulties, the old spans being supported on falsework and dismantled; the required change of two feet in grade was accomplished by raising one end of each old span to the new grade as the adjoining new span was erected, thus forming what might be called a progressive incline. The erection of the draw-span did not go as well. It did not begin until Feb-

ruary, due to delay in receiving the steel work. The weather was then very cold, and the contractors felt justified in proceeding with the erection of the river arm of the draw-span on their own responsibility and under authority from the Commanding Officer of the Arsenal, though against the writer's protest. During this period the trains were carried on falsework only, the old draw-span having been removed. On February 23rd, the river rose suddenly and the thermometer went up to forty degrees above zero. The river kept on rising, and the situation was becoming more and more critical. In the meanwhile, the contractors were pushing the erection of the river arm with desperate energy in the attempt to close half of the draw-span before the ice went out. On February 25th the ice above the bridge broke up and carried with it the falsework and steel thus far erected. Twelve hours more would have completed that arm of the span, and twenty-four hours more would have seen the structure entirely safe. The main problem then became how to shorten the inevitable time of interruption to the railway traffic and how to let boats through by the time the navigation season opened. The falsework in the shore channel of the draw remained intact. The falsework in the river channel was replaced in five days, working day and night, and the railway traffic was thus reëstablished. In about four weeks the navigation season was due to open. It was out of the question to replace the necessary steel and complete the erection in this short time. The resident engineer suggested building a temporary lift-span, and his suggestion was carried out in a rather interesting manner. The railway company happened to have a 147 ft. 5 in. combination span on their road which could be spared and which fitted into the problem very well. A very simple and easily constructed temporary lifting device was designed. Two timber towers for lifting the span were built, and the lift-span was assembled and put in operation on March 26th, or one month and one day after the accident. This was none too early, as on March 27th the first boat passed through. (Fig. 8.) It took one minute to raise and the same time to lower the span. The raising device consisted of steel rope and sheaves, without counterweight, operated by two hoisting engines, one near each end of the span. Proper indicators permitted the engineer at each end to keep the span level while it was being raised or lowered. The operation was successful beyond expectations. The

FIG. 8.



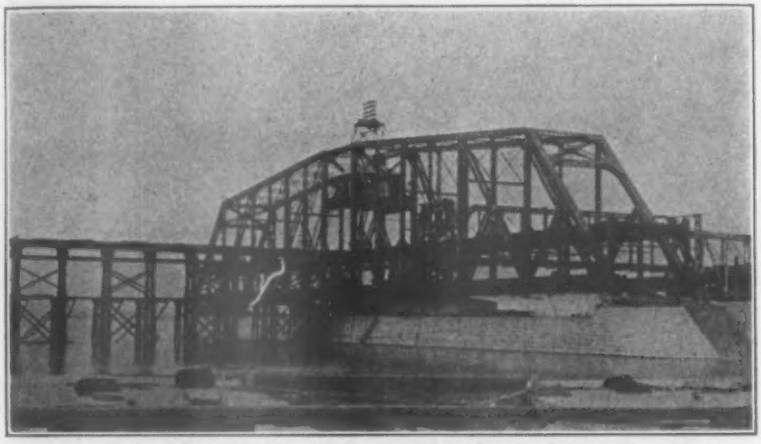
Rock Island Bridge. Temporary lift-span in operation.

motion of the span was very steady and it came down on its bearings without the least shock. It remained in operation until May 24th, when the new draw-span, which was then erected on the draw protection, or at right angles to the centre line of the bridge, was swung into place. (Fig. 9.) The lift-span was

operated at an average of over fourteen times a day and as many as twenty-five times in a single day.

When the new draw-span was finished and ready for operation, everything was prepared in advance to reduce the time of swinging it into place to the minimum. It was one of the busiest days in the writer's experience. The lift-span was partly raised and suspended by proper rigging from the adjoining steel work; the temporary towers were then toppled over into the river

FIG. 9.



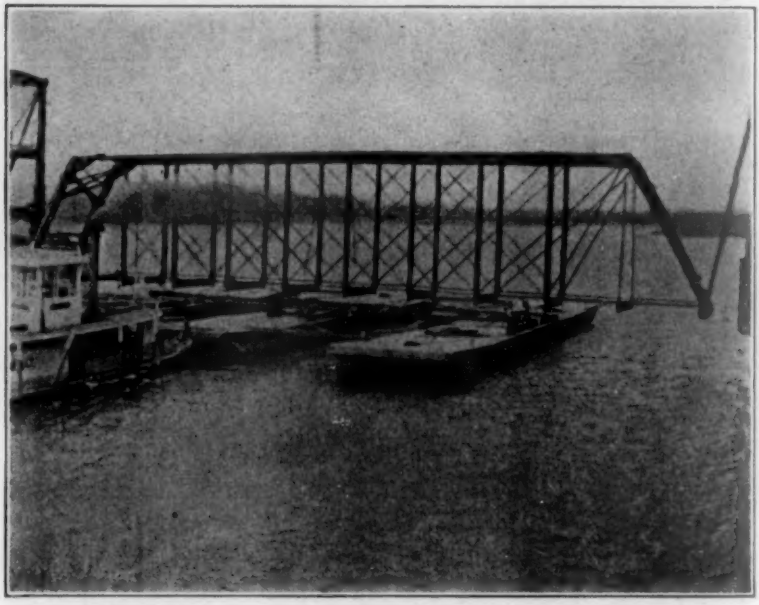
Rock Island Bridge. Draw-span erected on draw protection.

and towed away. (Fig. 10.) Three barges tied together were brought under the lift-span, which was then lowered onto them and towed away. While this operation was going on, the false-work in the shore channel was being removed by a specially constructed derrick car. As soon as both channels were cleared, the new draw was swung into place. The actual time of interruption to navigation was twenty-four hours and twenty minutes, and to railway trains ten hours and thirty-five minutes.

There is a bridge over the Mississippi River at Keokuk, Iowa, which carries steam railroads, interurban cars, vehicles and pedestrians. In the old bridge, this varied traffic was carried on one deck, and of course there was much interference and constant danger of accident. In rebuilding the bridge for heavier railway loads, it was necessary to maintain constantly all but the pedestrian traffic. The new bridge was designed to accommodate the

vehicular and pedestrian traffic on an upper deck above the railway track. The entire work of reconstruction was done without interruption to traffic of more than two hours at a time and that interruption occurred only at stated times of day so that traffic could adjust itself to it. The vehicles were carried on the lower deck, where the pavement was left undisturbed, until the upper

FIG. 10.



Rock Island Bridge. Temporary lift-span being lowered onto barges.

deck was ready to receive it. Falsework was used throughout. The draw-span was erected during closed navigation.

A very unusual problem was the reconstruction of the Cincinnati Southern Bridge at Cincinnati. The first bridge was built in 1876 and was a single-track structure, the river part of it consisting of two 300-foot spans, a channel span of 519 feet (then the longest simple span in existence), and a draw-span 370 feet long. (Fig. 11.) The loading on the bridge built so long ago was naturally restricted; the locomotives were limited to 65 tons and freight cars to 115,000 pounds gross weight. The object of reconstructing this bridge was not only to increase the capacity as

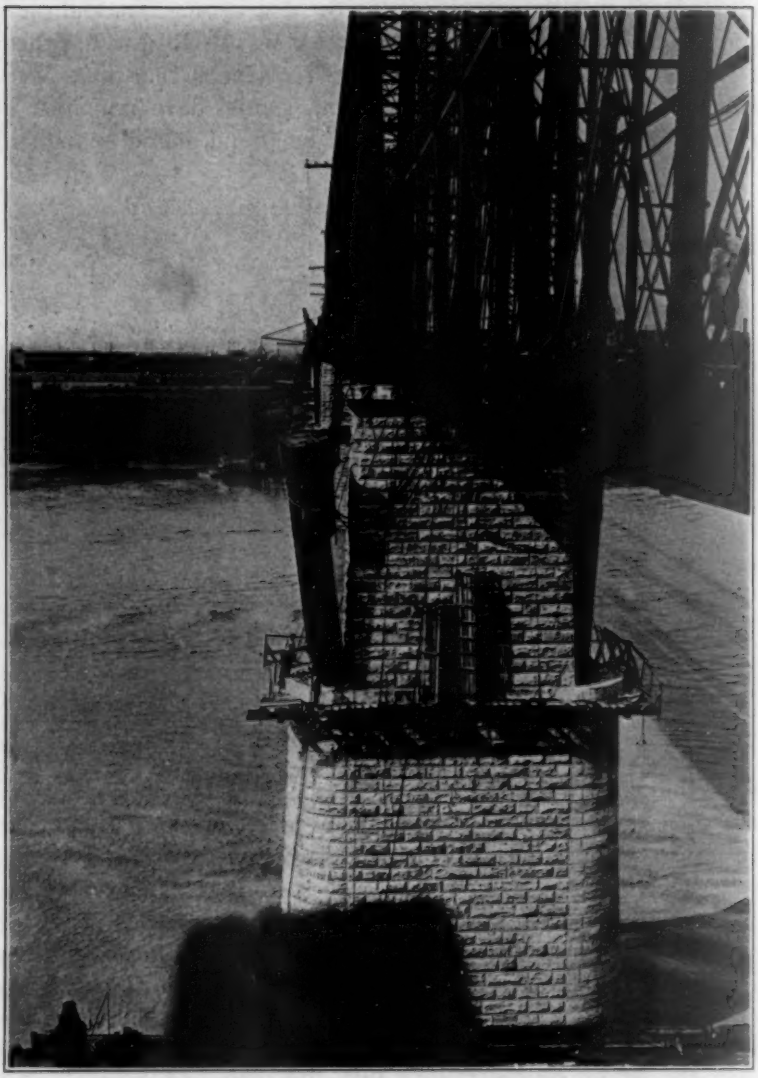
to weight of rolling stock, but also as to number of trains. A double-track modern structure was decided upon. The old piers were found in excellent condition, and it was decided to use them to support the new spans. It is rather remarkable that these piers, built of limestone and natural cement, should have remained in service for forty-five years and then be found sound enough to

FIG. 11.

Cincinnati Bridge. Old structure.

carry the greatly increased modern loads and a much heavier new steel superstructure. These piers were not long enough at the top to support the greater width between trusses of the new spans which was to be 32 feet, 4 inches, on centres; but they are 42 feet long below the starling coping and therefore this increased width could be carried to the top without adding anything to the piers below high water level. Consequently, the starling copings were removed and the projections levelled off. Columns were placed on these projections to support the end-bearings and to carry the heavy concentrations into the pier. (Fig. 12.) To distribute the load more equally to the base of the piers, these columns were placed closer together at the bottom than the distance between trusses, making them lean outward at the top. They were connected at the top by heavy girders which served

FIG. 12.



Cincinnati Bridge. Placing main pier columns, Pier III.

to transmit part of the superstructure load to the centre of the pier. This was done by wedging under them at the centre sufficiently to develop the required centre reaction. They were then

concreted in. In this manner the weight of the new steel and of the heavy traffic is well distributed over the entire area of the pier and foundation. The columns were hooped with steel reinforcing rods which also tied them to the body of the pier. Rods and columns were then embedded in concrete.

In granting the permit for the reconstruction, the War Department made it a condition that no falsework be placed under the 519-foot channel span or under the adjoining 300-foot span. This condition called for cantilever erection. The clear-

FIG. 13.

Cincinnati Bridge. Erecting 518-foot span by cantilever method around the old superstructure.

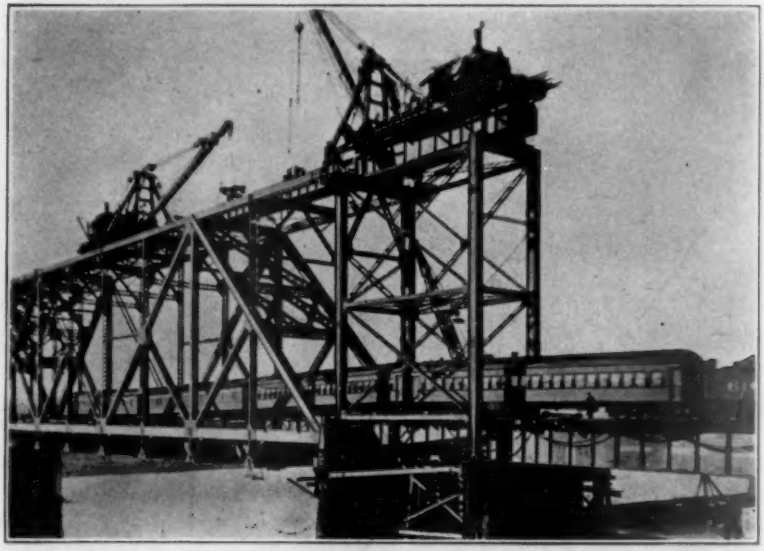
ance above water must remain the same as in the past, but since the floor of the double-track bridge is four feet deeper than the old floor, the grade on the bridge had to be raised correspondingly.

And so the given conditions of the problem were to dispense with falsework under the two main river spans, which meant cantilever erection; to erect the new steel work around the old spans; to raise the grade four feet; to change the single track into double track; to remove the old trusses from inside the new ones and to do all this without interruption to traffic.

The new 519-foot main span and the two 300-foot spans were designed as a continuous structure over four supports. This permitted the trusses to be erected by cantilever method. (Fig. 13.) This method required that the erection equipment, consist-

ing mainly of two powerful derrick cars, be placed on top of the trusses. The track for this equipment was built of stringers placed on top of the new sway bracing, which stringers were later to support the permanent tracks of the bridge. The material for the new trusses was handled on a track supported on specially constructed brackets outside the trusses. The raising of grade was accomplished by first suspending the new floor beams four feet below the final level, in this manner supporting the old spans

FIG. 14.



Cincinnati Bridge. Run-off from raised tracks to old level, showing also temporary steel tower to support derrick traveller.

before dismantling them. As the old spans were removed, the new floor beams with two lines of stringers were raised to their final position. (Fig. 14.) A movable ramp or incline was used to make the transition from the new grade to the old.

Since the stresses in a continuous structure are dependent on the reactions at the supports, these reactions were carefully adjusted by powerful jacks, and the resulting stresses verified by extensometer measurements.

Thus summing up, the piers were prepared for the columns and the columns set before the erection of the new spans was

started. (Fig. 15.) The new trusses were then assembled outside of the old structure by cantilever method. The new sway bracing was placed between the members of the old spans. The closure was made at the centre of the 519-foot span. The floor of the new trusses was placed temporarily below the old floor. The old trusses were then removed from inside the new spans, the new floor raised into its final position, and both the new tracks completed. (Fig. 16.)

A vehicular and street railway bridge at Omaha, built in the

FIG. 15.

Cincinnati Bridge. New lift-span. Old pivot pier still in place.

eighties, was recently widened so as to double its capacity. Its carrying capacity as to loading was more than doubled. This had to be done in order to provide for heavy automobile trucks and heavier interurban cars. The bridge consists of one 400-foot through-span and a number of deck-spans, all resting on cylinder piers. The through-span was the most difficult one to deal with. It was, of course, desirable to utilize the steel work of the existing trusses, which was in excellent condition. It was decided, therefore, to spread these trusses from 28 feet to 56 feet on centres, and to build a new truss midway between the old ones. For that

purpose a line of new cylinder piers was built on the downstream side to support the greater width. (Fig. 17.) Each pier, then, consisted of three cylinders instead of two. But this did not quite solve the problem. The two old trusses, which were to be the outside ones, were not strong enough to carry their portion of the increased loading. To reinforce the individual members of those trusses would have been an expensive operation, requiring dismantling and shipping to some shop and back. This was avoided

FIG. 16.

Cincinnati Bridge, showing new superstructure in place, old superstructure removed.

by making the new centre truss correspondingly heavier and by designing the sway bracing heavy enough to transmit the portion of the live load necessary to relieve the outside trusses. The centre trusses were designed as nearly as possible like the old trusses. The length, height and panelling are the same. They are made to deflect equally with the outside trusses by the stiff sway bracing. The deflections for maximum loading being equal, the unit stresses in the corresponding members of the old and new trusses are the same; hence the load carried by the old and the new trusses is in proportion to their sections. For instance, had the sections of the new truss been made three times those of each of the old trusses, one-fifth of the live load would have been carried by each of the outside trusses and three-fifths by the centre truss. In other words,

the old truss, instead of carrying one-half the load on the single roadway, would then carry one-fifth only of the double, or two-fifths of the single roadway load, or a reduction of 10 per cent. If the loads have increased by 10 per cent., the outside trusses will be subjected to the same unit stresses in the new bridge as in the old bridge.

The Quebec Bridge, after its first failure, offered a very

FIG. 17.

Omaha Bridge. New centre truss in place. Old truss moved out part of the way.

serious and difficult problem in design. The failure was ascribed to one or all of the following three reasons:

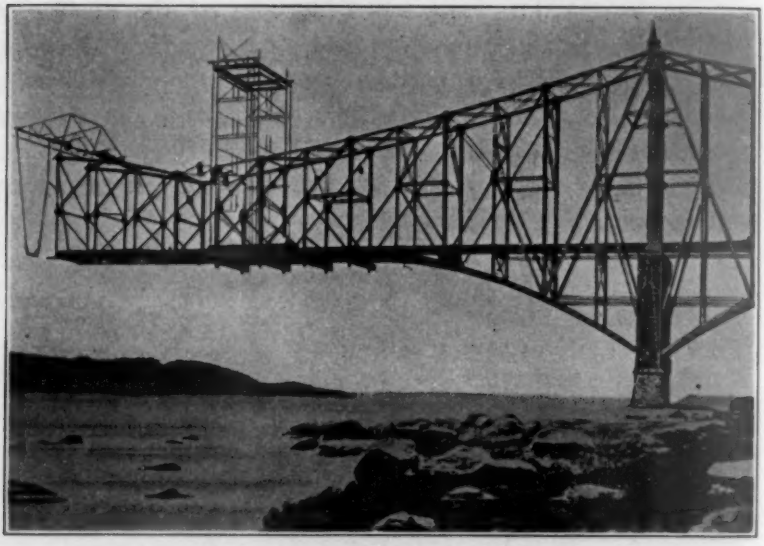
(1) Insufficient lacing of the compression chords;

(2) High erection unit stresses;

(3) Joints in bottom chord not having a full bearing during erection.

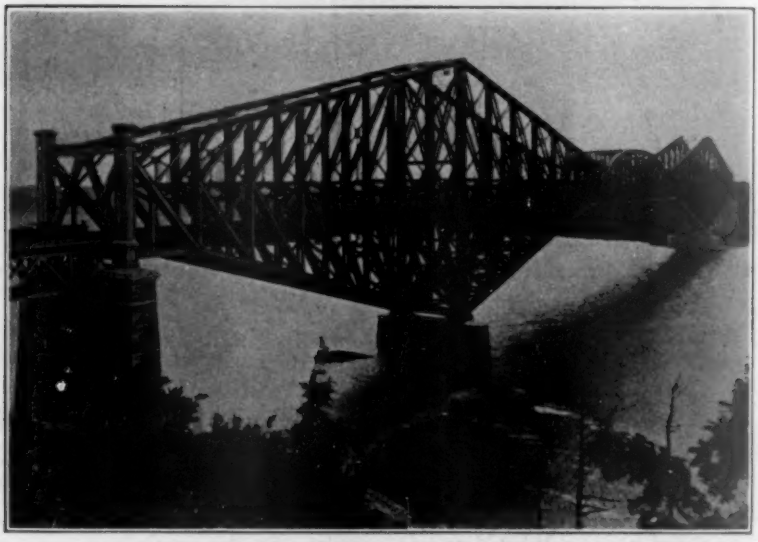
To correct the first two points, it was only necessary to increase the lacing and to increase the sections where needed. The third point required careful study. In the first place, a more

FIG. 18.



Quebec Bridge, original design with carved bottom chords.

FIG. 19.



Quebec Bridge. Final design with straight bottom chords.

rigid design was decided upon. (Fig. 18.) In the original design, the bottom chords of the cantilever arm were curved because of certain demands of navigation requiring a wide channel with a 150-foot clearance above water. But such a design was obviously subject to considerable distortion. Then again, erecting the suspended or centre span by continuing the cantilever method to the centre of the 1800-foot opening threw very heavy bending stresses into the anchorage span and the cantilever arm. This accentuated the distortion and consequent lack of bearing in the chord joints. It was therefore desirable to make the design stiffer, to see that the joints have full bearing during erection, and to eliminate the additional distortion during erection produced by the cantilever action of one-half of the suspended span.

The accepted design has straight top and bottom chords. (Fig. 19.) This was made possible because the Government rescinded its requirement for a wide channel with full height of 150 feet. The distortions during erection of the adopted form of truss were very much smaller than in the original design. It was further decided to float the suspended span on barges and after towing it into position lift it into place. As an additional precaution, the joints in the bottom chords of the anchor-span and of the cantilever arm were riveted while in full bearing.

The ever-increasing use of alloy steels of high grade, such as nickel steel, chrome-nickel steel, and silicon steel, is facilitating the design of long spans and increasing their practicable length. Silicon steel, which may now be obtained at a comparatively low cost, is especially useful and often takes the place of carbon steel in ordinary structures. Because its strength is about 40 per cent. greater than that of carbon steel, its use is often a source of economy. By using alloy steels, unusual problems in long-span design become more practical and present fewer difficulties. An independent span of 1000 feet could easily be built now, or even a 1000-foot draw-span with two 450-foot openings, or a cantilever bridge of 3000 feet clear span. Alloy steel has not yet been used in wire cables of suspension bridges, but nickel and silicon steel are being used extensively on the Delaware River Bridge. Nickel steel has been used in the stiffening trusses of the Manhattan Bridge in New York, in the truss members of the Quebec Bridge, and in several other large structures.

Oceanic Trades Conflicts.—JULIUS KLEIN, Director of the U. S. Bureau of Foreign and Domestic Commerce, presented in a speech at a luncheon of the American Manufacturers Export Association, New York, March 25th, some statements in regard to the development of American export trade, especially with reference to the possible competition which that trade may meet on the part of some of the other manufacturing countries. An increase of 10 per cent. in the value of exports is noted for 1924 as against 1923. This shows undoubtedly a gratifying increase and yet the valuation of exports may be somewhat misleading as the prices may have increased. Mr. Klein's views upon the possibility of serious competition of the leading manufacturing nations are mainly optimistic. Alarming prophecies are indeed being made as to the serious inroads that other nations may make into our export trade, but Mr. Klein finds that they depend in almost every case upon the assumption that the trade to the competitive areas has already reached a point close to saturation and that the issue, therefore, is merely a question of the relative strength of the three leading contestants. This he regards as a totally erroneous inference, especially as it presumes a rigidity in the standards of living in these lands. It is interesting to note that the exportations from the United States to the countries which are essentially non-manufacturing consist largely of moderate-priced automobiles, motion picture films, labor-saving machinery, ready-made clothing, electrical specialties and office equipment. Interesting statistics concerning the variations in the relative export trades of Great Britain, Germany and the United States are included in the address. H. L.

A New Method of Examining the Interior of Pearls. B. SZILARD. (*Comptes Rendus*, Feb. 9, 1925.)—Since the industry of growing pearls has become of so much importance in Japan, it has served as a challenge to the ingenuity of mankind to discover a method of telling natural from cultivated specimens without destroying their value in the search for information. One such method of discrimination is based on the use of X-rays. The present author uses the microscope. A pearl on the stage of the instrument, strongly illuminated, shows but little of its structure. The light coming to the surface of the pearl is there reflected. This reflection can, however, be in large part avoided by immersion in a liquid of the same refractive index as the pearl. When, therefore, the gem is put into oil of cedar, its interior is penetrated by the light and details of structure are made visible. Cultivated pearls proclaim their origin by showing parallel streaks, when placed in a certain position under the microscope, while natural specimens in no case showed this appearance, though hundreds were examined. G. F. S.

MODERN X-RAY TUBE DEVELOPMENT.*

BY

WILLIAM D. COOLIDGE, Ph.D.

General Electric Company.

A. INTRODUCTION.

THE early X-ray tube of Röntgen, the Crookes tube, was greatly improved by Campbell-Swinton through the introduction of a platinum target and by Jackson, who turned to account a former discovery of Crookes and used a concave cathode.

A later step of great importance was the addition of a device for regulating the vacuum of the tube.

For medical diagnostic work, the thin metal target was soon replaced by a heavy mass of metal consisting usually of two parts, a refractory metal face to take the cathode-ray impact and a heavy back-plate consisting of some good heat-conducting metal which should serve to lead away and temporarily store the heat liberated at the focal spot. It was necessary that the two members of the target should be in intimate thermal contact with one another.

Platinum and copper had come into very general use for the refractory metal face and back-plate, respectively.

As soon as it became available for the purpose, ductile tungsten was substituted for the platinum face of the target.[1] Tungsten had a slightly lower atomic number, but, with its higher melting point, lower vapor pressure, and greater heat conductivity, it made possible the production of much higher X-ray intensity per unit of focal area.

The next improvement in the X-ray tube consisted in the removal of the gaseous atmosphere and the use of a hot cathode as a source of electrons.

B. TYPES OF HOT-CATHODE TUBE DEVELOPED.

Tubes of this type have now been developed to operate at voltages up to 250,000 (max.) and to handle, in some cases, as much as 8 or 10 kilowatts of energy. Some of these tubes are intended for intermittent service and some to be used continuously.

* Address delivered Wednesday, September 17, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

[1] COOLIDGE, W. D.: *Trans. A.I.E.E.*, Vol. 31, part 1, pp. 1219–1228 (1912).

The focal area can be made of any desired size and has, in our experiments, ranged in diameter from perhaps 1/100 of an inch to 1¼ inches.

The following methods have been employed for dissipating the heat liberated in the anode:

(1) Making the entire anode head of tungsten and letting this come to a high temperature and radiate.

(2) Providing the anode with a heavy copper stem which conducts the heat to a radiator outside of the tube.

(3) Providing the anode with a heavy copper stem and then immersing the whole tube in oil.

(4) Making a portion of the anode hollow and cooling it by circulating water.

Some of these tubes are intended to operate directly from a transformer, while others are intended to be used on outfits provided with some auxiliary means of rectification.

It is not the purpose of the present paper to describe any of these tubes in detail, as that has been done elsewhere,[2] but rather to call attention to some of the fundamental principles involved.

C. SOME PHYSICAL PRINCIPLES INVOLVED.

(1) CURRENT CONTROL.

The electrons are supplied by heating a tungsten filament comprising a part of the cathode structure, and the current flowing from cathode to anode can either be saturated or limited by space charge. Wherever flexibility is desired it is better to design the tube for saturation, for the allowable energy input is limited either by the size of focal spot or by the anode construction, and when a low voltage is used, it is often desirable to use as much current as possible. With a space-charge-limited tube, less current would be available at low voltages than at high.

(2) SHIELDING OF FILAMENT.

The electrostatic pull on the hot and therefore soft tungsten filament can easily be made sufficient to draw the filament to the anode with a consequent short-circuiting of the tube. This

[2] *Phys. Rev.*, **2**, 409–430 (1913); *Am. Jour. Roentgen.*, **2**, pp. 723–725 and 881–892 (1915); *Gen. Elect. Rev.*, **20**, pp. 272–281 (1917); *Am. Jour. Roentgen.*, **4**, pp. 56–62 (1917); *Gen. Elect. Rev.*, **21**, pp. 56–60 (1918); *Jour. Roentgen.*, **2**, pp. 149–176 (1919); *Am. Jour. Roentgen.*, **6**, pp. 175–179 (1919); **7**, pp. 181–189 (1920); **9**, pp. 77–101 (1922); *Amer. Jour. Roentgen. Rad. Ther.*, **10**, pp. 884–889 (1923); *Jour. Radiol.*, Jan., 1924, pp. 9–12.

electrostatic force upon the hot filament is kept within safe limits by the use of sufficient spacing between cathode and anode and by the shielding action of the focussing device.

(3) CONTROL OF SIZE OF FOCAL SPOT AND DISTRIBUTION OF ENERGY.

In tubes intended for diagnostic work, it is desirable that the X-ray source should be as small as is consistent with the use of the required amount of energy. To fulfil this requirement, it is necessary that the distribution of energy over the surface of the focal spot shall be as uniform as possible. Some indication of the energy distribution can be obtained by intermittent short-time operation of the tube with gradually increasing amounts of energy, inspecting the focal spot after each operation of the tube. With a certain load, it will be observed that a certain pattern on the focal spot has been melted. If too much energy is used, in the course of these experiments, the whole focal area will melt. This will interfere with subsequent observations unless the tube is then operated for a short time (a minute will probably suffice) on some source of intermittent current, such as a transformer (anything but a constant-current, constant-potential machine). This will roughen (frost) the smooth melted area so that subsequent melting can be observed.

A much better method for investigating the energy distribution consists in making X-ray pin-hole camera pictures of the focal spot.[3] If variously timed exposures are made, one will be found of suitable photographic density to indicate the energy distribution; the total focal area can be obtained from a long exposure.

The focal spot can be changed in shape, size and uniformity of energy distribution by changing the size or shape of the filament spiral or focussing device, or by changing their relative locations. It is also affected by the shape and relative location of the anode and by the location of both electrodes in the glass bulb. No better method for securing a tube design that will give a suitable focal spot has been found than that of trial and error.

(4) PROTECTION FROM "INVERSE" CURRENT WITH A. C. OPERATION.

If a tube is to operate on alternating current, directly from a transformer, it must rectify its own current and, as it cannot do this with more than a certain amount of overload, two contin-

[3] *Gen. Elec. Rev.*, April, 1917, pp. 272–281.

gencies must be guarded against. If current passes through the tube in the wrong direction, the "inverse" electron stream must not strike the glass wall of the tube since if it does, it will lead to local heating and cracking of the glass. Nor must it strike the cathode filament spiral, for if it does, it will heat it, causing more electron emission at this point. Hence a more severe bombardment of the focal spot will result, and, therefore, more "inverse" current, in which case the tube runs away. In general, it will be found that the "inverse" electron stream, if it exists, is an essentially straight parallel beam leaving the focal spot in a direction essentially normal to the target face. If the electrodes were symmetrically placed in the tube, and if the target face was normal to the tube axis, the "inverse," if it existed, would strike the cathode filament and cause a runaway. This has often been observed in experimental tubes. If, however, the target face is inclined at an angle of 45° or less, with the plane normal to the tube axis, and if the focussing device is made large enough, the "inverse," if it exists, is intercepted by the focussing device. It is to enable the latter to withstand "inverse" bombardment that a high melting metal, molybdenum, has been used for the focussing device.

(5) SHIELDING OF GLASS FROM POSITIVE-ION BOMBARDMENT.

The focussing device has the further function of shielding the glass, back of it, from destructive positive-ion bombardment during the early stages of electrical operation of the tube on the pump, that is, while the gas pressure is relatively high.

(6) TARGET CONSTRUCTION.

If a composite target is used, it is of the utmost importance to secure good thermal contact between the refractory metal facing and the back-plate. This necessitates welding or soldering, as the best mechanical joint is entirely inadequate.

With a solid tungsten target, which gets rid of its heat by radiation, it is, on the other hand, better to have a mechanical joint between the target head and the supporting molybdenum stem, as this, because of its poor thermal contact, greatly reduces the flow of heat to the glass of the anode end of the tube. It, furthermore, prevents alloying, which might otherwise take place, between the tungsten and molybdenum, by keeping the latter from getting as hot at the junction as it would with a welded joint.

(7) CONFIGURATION OF ANODE ARM.

The inside of the bulb operates at essentially cathode potential; so that the anode arm is subjected to nearly the full potential difference applied to the tube. This is indicated by the fact that the glass bulb is not subjected to continuous electron bombardment which would, if it took place, manifest itself by local heating, fluorescence and X-ray emission. It is further indicated by the fact that the cathode arm can be made very short without affecting the behavior of the tube. The tube can even be encased in metal connected to the cathode without affecting tube behavior, provided the vacuum is sufficiently good. If, however, a little gas is liberated within the tube, it will, under these conditions, promptly puncture, even though the amount of gas is so small that it would otherwise do no harm.

The anode should not touch the inner wall of the anode arm near the point where this is attached to the bulb, as there will otherwise be destructive sparking to the glass at the point of contact. The anode arm should, furthermore, not be too large for a given size of anode support. It seems necessary to have a relatively long and narrow space in the anode arm surrounding the anode support. The function of this relatively long and narrow space appears to be to keep the reflected and secondary electrons, which come out of the focal spot, from getting far down in the anode arm and so subjecting the glass there to too high a potential gradient.

(8) TEARING OF TARGET FACE.

When a tube is operated on interrupted current, as from the induction coil or transformer, there is a very pronounced tearing action manifested in the metal at and close to the focal spot. This is due to the rapidly alternating expansion and contraction of the target face at this point, due to the heating effect of the electron bombardment and the subsequent cooling which takes place as the heat flows to the adjacent target metal. This action is absent when a tube is operated on continuous current and constant potential. With transformer operation, the tearing effect may be so pronounced in the case of a water-cooled anode that, even with the target face never exceeding say 700° C. in temperature, the target will, in perhaps one hundred hours of operation, tear to a depth of a quarter of an inch. With the cooling water brought close to the target face, the target may tear until water leaks into

the tube. This has often been observed. It may be prevented by avoiding too steep a temperature gradient in the target. For a given amount of energy to be dissipated, the temperature gradient can be made as small as is desired by a sufficient increase in the size of the target face and in the focal spot. If a certain temperature gradient is not exceeded, the forces of expansion and contraction which are set up do not exceed the elastic limit of the material, and, therefore, no tearing results even with the repeated stress.

(9) EFFECT OF BULB SIZE ON PERFORMANCE.

The smaller the tube, the more difficult it becomes to exhaust it so that it will operate satisfactorily on a given voltage. This is quite apart from the practical difficulty of sealing a small tube off from the pump without causing a substantial pressure increase by the sealing-off operation.[4] In the small tube the glass walls are subjected to greater dielectric strains because of their closer proximity to the electrodes. The difficulty can be reduced by resorting to a greater wall thickness as the bulb size is decreased.

Not only is there no objection to increasing the wall thickness in small tubes, but this procedure makes it possible, through the use of glass having a high lead content, to provide a substantial amount of X-ray protection in the tube walls. A small thin window of transparent glass may be provided for the emergent beam of X-rays.

The beneficial effect of the thicker wall in small tubes is manifested not only by diminished puncturing troubles, but also by quieter operation. The thick-walled tube will set up less surges in the high-tension circuit and will operate with less crackling noise.

The surge trouble experienced with small thin-walled tubes is doubtless caused indirectly by sudden changes in the distribution of charge over the surface of the bulb and directly by sudden changes in the magnitude of the high-tension current caused thereby. That such is the case is indicated by the following

[4] This difficulty arises from the fact that, to seal a tube off from the pump, it is necessary to heat locally the glass connecting-tube capillary to the point of actual fusion, and whenever glass is heated hotter than it has been before while connected to the pump, it gives off large amounts of gas. With small tubes it is better to use small capillaries and, in sealing off, to heat as short a length of the capillary as possible.

facts: With very small tubes, the current which can flow from cathode to anode is largely determined by charges on the walls. An extreme case illustrating this point was that of a cylindrical quartz tube about 0.5 cm. in internal diameter, having as electrodes tungsten filaments situated about 3 cm. apart. With the cathode filament heated, this tube, operating from a direct-current, constant-potential source, sometimes carried an appreciable current with as little as 1000 volts. When this condition pertained, the walls of the tube fluoresced and heated strongly, indicating that they were not operating at cathode potential but that, upon being bombarded by electrons, they were giving secondary electron emission, which allowed the primary electron bombardment to continue. If this tube was rubbed slightly with the finger in the zone between the electrodes, current flow immediately stopped and the tube would then carry no current even with 40,000 volts. If, however, X-rays from an external source were turned on the tube for an instant, it became as highly conducting as at first. Contact of the finger with the quartz had charged the latter negatively, and the presence of this negative charge on the outside of the quartz had acted, as does the negative charge on the grid of a pliotron, to prevent current flow through the tube. X-rays ionized the air around the tube and allowed the negative charge on the outside of the quartz to escape. When high voltage was put on the tube before lighting the filament, it was also found possible to put the tube in a condition where it would carry no current, even with 40,000 volts, when the filament was subsequently lighted. This condition was not affected by putting on X-rays. In this case the discharge was inhibited by the presence of a negative charge on the inner surface of the quartz, coming from high-speed electrons which had left the filament, when it was cold, under the influence of the high-potential gradient.

In the light of the preceding experiments, we should expect that, with small tubes, changes in the distribution of charge over the surface of the bulb would result in rapid and considerable changes in the high-tension current flowing through the tube. These would give rise to violent surges.

(10) EFFECT OF OPERATION OF TUBES ON THEIR VACUUM.

(*a*) *Tubes Having Solid Tungsten Anodes.*—Tubes having solid tungsten anodes show, in general, a slight improvement in vacuum during the first few minutes of operation after they are

sealed off from the pump. During subsequent *normal* operation there is, as a rule, nothing in their behavior, throughout their life, to suggest either improvement or impairment of vacuum.

If, however, such a tube is badly overloaded, even for a small fraction of a second, the vacuum may be so seriously impaired that the tube is no longer operable. The gas, in this case, apparently comes from the target in the immediate neighborhood of the focal spot. Such impairment of vacuum does not take place if the tube has had equally heavy overloads while operating on the pump.

A certain design of tube which will operate continuously for hundreds of hours at 200,000 volts (max.) and 5 milliamperes will show, at 8 milliamperes, a rapidly deteriorating vacuum after perhaps ten hours. This vacuum change will not take place if a current of air from a blower is kept directed on the bulb.

A similar tube with a larger target and a larger bulb was immersed in a bath of water-cooled oil and was then operated continuously at 200,000 volts and 30 milliamperes for forty hours, at the end of which time it was accidentally broken. The glass wall of this tube at one point, at the cathode end of the bulb, was strongly eroded on the inside. Over an area of more than a square centimetre, the wall thickness had, in this way, been reduced from an original thickness of about five-tenths to only five- or six-hundredths of a millimetre.

It seems possible that, when the tubes having solid tungsten anodes carry continuously more than a certain load, the inner surface of the bulb may become heated to such a temperature, by radiation from the anode, that there is, with the high voltage, some electrolysis of the glass with consequent liberation of potassium or sodium on the inner surface of the bulb. Experiment has shown that, where the glass is intentionally electrolyzed in a finished tube, the vacuum becomes seriously impaired. (This intentional electrolysis is carried out at 200° C., and check experiments have shown that the impairment of vacuum is not caused by the mere heating of the tube.) Such impairment of vacuum would lead to serious bombardment of the glass, and this bombardment might, in case the tube was immersed in oil, go on unobserved until the wall had been locally eroded to a great extent. The oil would reduce the local temperature due to the bombardment, and so prevent cracking. The unmistakable effect

of the air-blast on the smaller tube, operating at 8 milliamperes in the air, suggested that the helpful action was due either to a lowering of the temperature of the glass or to the removal from the external surface of the bulb of strongly ionized air. With later tubes, in which the copper-backed tungsten anode is water-cooled and the tube is operated in the air without forced air circulation, there has been no evidence of vacuum deterioration, even with a load of 50 milliamperes at 250,000 volts (max.). With these tubes there is but little heating of the glass. It, therefore, seems probable that heating of the glass, accompanied perhaps by electrolysis, has been the determining factor in the experiments in those cases where a gradual impairment of vacuum has taken place on continuous operation.

(*b*) *Tubes Containing Copper in the Anode Structure.*—With tubes in which the target consists of a tungsten button set in copper, marked changes in vacuum may occur with use. If the target, as a whole, is allowed to get red hot, so much gas may be liberated from it that the vacuum becomes too poor for the continued safe operation of the tube. If the target is then cooled, it will, in general, be found that the gas is quickly taken up by the copper and that the tube operates as it did in the first place.

By employing much more drastic exhaust methods while the tube is on the pump, the target can be brought to such a condition that, after sealing off, a large mass of copper near the working face of the target can even be melted without evidence of impairment of vacuum.

If the target is kept at a sufficiently low temperature, as by immersing its external end in cold oil or by means of internal water-cooling, it has been found that the vacuum may be materially improved, after sealing off from the pump, by an "aging" process, in which the voltage applied to the tube is at first perhaps a third of its final value and is very gradually increased.

That the vacuum obtained by this "aging" process may be much better than that originally produced by the pump is indicated by the following experience with tubes having water-cooled anodes and intended to be operated at as much as 50 ma. and 250,000 volts. If, in connection with the exhaust, these tubes are operated on the pump with as much as 200,000 volts, their bulbs rapidly darken from metallic deposit, showing that at the vacuum maintained in the tube by the pump (and this applies even with a

relatively unrestricted connection between the tube and the pump) there is at 200,000 volts a considerable positive-ion bombardment. If such tubes are operated on the pump at voltages not in excess of say 140,000, their bulbs show no appreciable metal deposit.[5] If they are then sealed off, they can, after "aging," be operated at 200,000 or even 250,000 volts without showing further metallic deposit.

(11) SECONDARY ELECTRON EMISSION FROM THE TARGET.

Secondary electron emission from the target is a very important factor, as it may result in a large X-ray production from the body and stem of the target and is doubtless responsible in no small measure for the electrical behavior of the tube.

Secondary electrons coming from the focal spot cannot go to the cathode, as they have not sufficient velocity; nor can they go to the glass bulb, as it is charged to the potential of the cathode. They are forced to go back and strike the target again, and many of them are doubtless again reflected and again forced to return to the target. Many of them have, as they come away from the focal spot, almost as high a velocity as that of the electrons in the primary cathode-ray stream. Röntgen-rays must be produced with each collision with the target, and it therefore becomes possible to study the phenomena by means of the X-ray pin-hole camera.[6]

Fig. 1 shows pin-hole camera pictures made with two tubes of the conventional form having 18 cm. and 9.5 cm. bulbs, the position of the bulbs being indicated by circles which have been drawn in. The pictures show that there is very little X-radiation from, and therefore very little electron bombardment of that portion of the target stem which is within the anode arm of the tube. This must be prevented by the negative charge on the bulb and on the adjacent end of the anode arm.

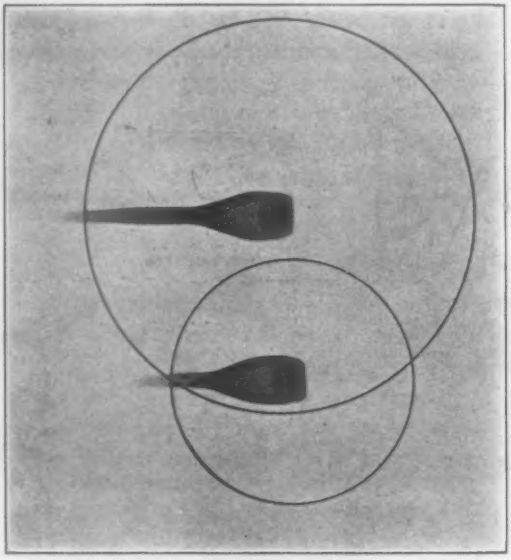
To give an idea of the relative intensity and penetrating power of the radiation from the focal spot and from the balance of the target, two röntgenograms of a Benoist pentrometer were made, one with the rays from the front and the other with the

[5] There is, of course, the usual amethyst coloration produced by X-rays, but this is easily distinguishable from the brown and black mirror-like metallic deposits referred to.

[6] All of the illustrations shown in this section are from an article by Coolidge and Moore published in the *Gen. Elec. Rev.*, April, 1917, pp. 272–281.

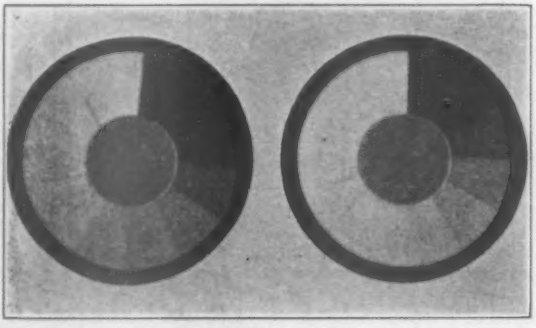
rays from the back of the target. These are shown in Fig. 2. Both were made with the voltage corresponding to a two-inch

FIG. 1.



Röntgenograms made with 7-in. and 3½-in. tubes.

FIG. 2.

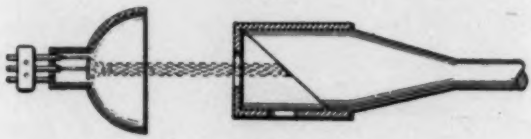


Röntgenograms of a Benoist pentrometer. Right, rays from front of target; left, rays from back of target. Exposure for front of target $\frac{1}{10}$ that for back of target. 2-in. spark gap.

spark between points. The one to the right was made by rays coming from the front of the target and was given, as measured in milliampere seconds, 1/10 the exposure of the other. The

central circular areas show very nearly the same photographic action, indicating that the total radiation from the back of the target is, photographically measured, about 1/10 of that from the front. This means that in the ordinary röntgenogram, made from the front of the target, there will be, photographically measured, about 1/9 as much radiation from the body and stem of the target

FIG. 3.

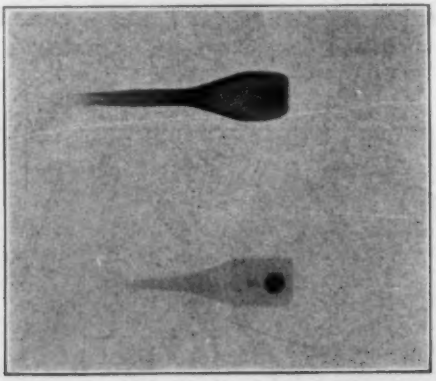


Metal hood on working end of target.

as there is from the focal spot. The penetration is seen to be about 3½ Benoist from the back and 4½ Benoist from the front.

In a similar experiment with a higher voltage, that corresponding to a 10-inch gap between points, the result was much the same. For equal photographic density in the circular areas of the pentrometer, that is under 0.11 mm. of silver, the required

FIG. 4.



Upper: Röntgenogram of target of standard tube. Lower: Röntgenogram of hooded target

times of exposure were, as before, 1 to 10. The penetration from the front of the target was 9 Benoist, and from the back 8 Benoist.

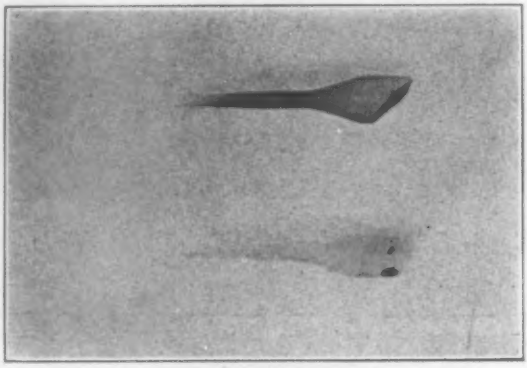
A method which suggested itself for preventing reflected and secondary electrons from leaving the target structure consisted in the use of a perforated metal hood attached to the working

end of the target. See Fig. 3, in which the primary electron stream is shown entering the hood through its front perforation; X-rays are taken out through the side opening.

The pin-hole camera pictures (Fig. 4) show that the electron bombardment of the body and stem of the target was greatly reduced by the hood. The two tubes used in making these pictures were, of course, operated under the same conditions; that is, the current, voltage, time and distance factors were the same.

The reflected and secondary electron emission is, of course, not prevented by the hood, but the electrons emerge from the

FIG. 5.



Same as Fig. 4 except that targets are turned sidewise.

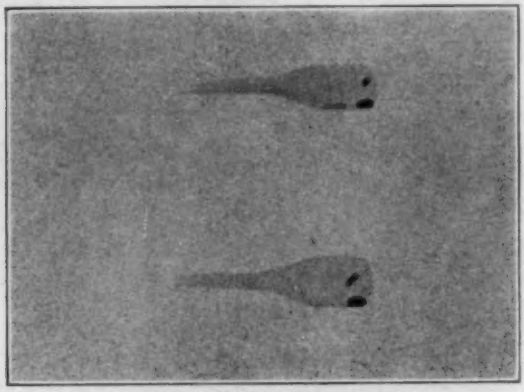
focal spot as before and then bombard the inner surface of the hood, where they produce X-rays, as is shown in the lower of the two pin-hole pictures reproduced in Fig. 5, in which the camera was exposed to the direct radiation from a small area on the inner surface of the hood close to the lower opening.

Fig. 5 also shows, by the difference in intensity on the upper and lower sides of the hooded target, that most of the electrons which still strike the body and stem of the target emerge through the lower opening in the hood.

This is confirmed by Fig. 6, made with two-hooded targets, differing only in this respect: That in the lower one a piece of thin tungsten foil (0.0008 inch thick) has been bound over the hole in the side of the hood. This would necessarily prevent any of the reflected or secondary cathode-rays from escaping at this point. An inspection of the pin-hole pictures shows that the use

of the foil prevented the difference in intensity on the two sides of the target and stem which is noticeable in the case of the hooded target without the foil. From the preceding experiments and from Fig. 8, which will be described later, it seems most probable that the small amount of radiation remaining on the surface and stem, in the case of the hooded target with the foil, is due to reflected and secondary cathode-rays coming from the focal spot and emerging through the hole in the end of the hood, through

FIG. 6.



Upper: Röntgenogram of hooded target. Lower: Röntgenogram of hooded target with tungsten foil.

which the primary cathode-rays enter. The number of electrons escaping in this way would naturally be relatively small, owing to the fact that from the focal spot the angle subtended by the hole is small, and to the further fact that these electrons have to move out against the electrostatic repulsion of the cathode.

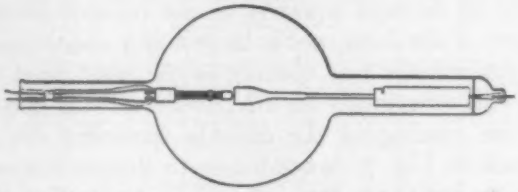
The pin-hole pictures made with the hooded target are, of themselves, sufficient to prove that at least all of that radiation from outside the focal spot which is eliminated by the use of a hood, must be due to cathode-rays emitted from the focal spot. Without such proof, one might think that much of this might be due to failure on the part of the cathode focussing device to bring to the focal spot all of the primary bundle of cathode-rays.

Figs. 4 and 5 show that, even with the two openings in the hood, the amount of radiation from the body and stem of the target was greatly reduced by the use of the hood. (Quantitative measurements with the ionization chamber showed that with the

design of hood used in this experiment, the reduction was to about 1/6 of what it was without the hood.)

Another method which was tried for returning the reflected and secondary electrons to the anode structure close to the focal spot consisted in locating the end of the cathode focussing device parallel and very close to the working face of the target (Fig. 7).

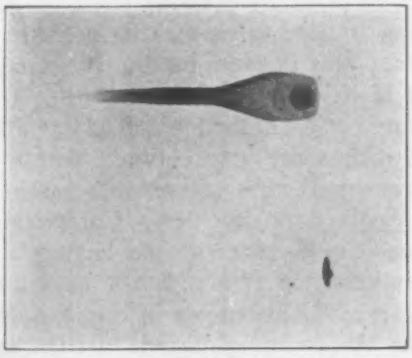
FIG. 7.



Tube in which working face of target is at a right angle to the axis of the tube. Distance between focussing device and face of anode, 2.3 millimetres.

The corresponding pin-hole picture is seen in Fig. 8. The X-rays were taken from the target in a direction making a very small angle with the face. The small round spot in the centre of

FIG. 8.



Upper: Röntgenogram of target of standard tube. Lower: Röntgenogram of target of tube shown in Fig. 13.

the target face is the focal spot, seen through the molybdenum focussing tube. The concentric circular ring around this is due to the reflected and secondary cathode-rays which have been forced to return to points close to the focal spot. Comparison of this röntgenogram with that of the standard tube above it shows how very effective this method has been.

While the methods indicated in Figs. 3 and 7 can both be used to reduce the flow of secondary electrons toward the anode arm of the tube and to reduce the X-ray production from the body and stem of the target, each brings with it certain limitations.

A tube with a hooded target, if operated directly from an alternating current source, will run away if overloaded to the point of allowing "inverse" current to pass, as the "inverse" current will be directed squarely at the cathode filament spiral. Furthermore, if the focal spot is large and a wide angled beam of X-rays is desired, the side opening in the hood must be made so large as to reduce seriously the effectiveness of the hood.

The close spacing of the cathode focussing device and the anode, shown in Fig. 7, is conducive to the production of undesired electron emission from the end of the focussing device because of the high-potential gradient.

D. TUBES WITH THORIUM AND URANIUM TARGETS.

For the production of short wave-length radiation, it seemed desirable to try thorium and uranium targets.

In 1915 we made up a tube having a target consisting of a button of thorium made by pressing thorium powder in a mold and then heating it close to its melting point in a tungsten tube vacuum furnace. This thorium button was clamped mechanically in a large split block of molybdenum.

It was operated on an induction coil at the voltage corresponding to a 17½-inch spark gap between points, and the X-ray intensity was measured under various thicknesses of aluminum by means of an ionization chamber. Corresponding absorption curves were made with another tube having a tungsten target and operated successively at a 7½, 10, 12½ and 20-inch spark gap. The results, which are shown in Fig. 9, indicated that at this high voltage the absorption coefficient[7] of the rays in aluminum was but little less for thorium than for the radiations from tungsten produced by the same voltage. (For all but the highest filter thickness, the intensity would appear, from the curves, to be lower for thorium than for tungsten at the same voltage, but this may well be due to the badly pitted condition of the focal spot.)

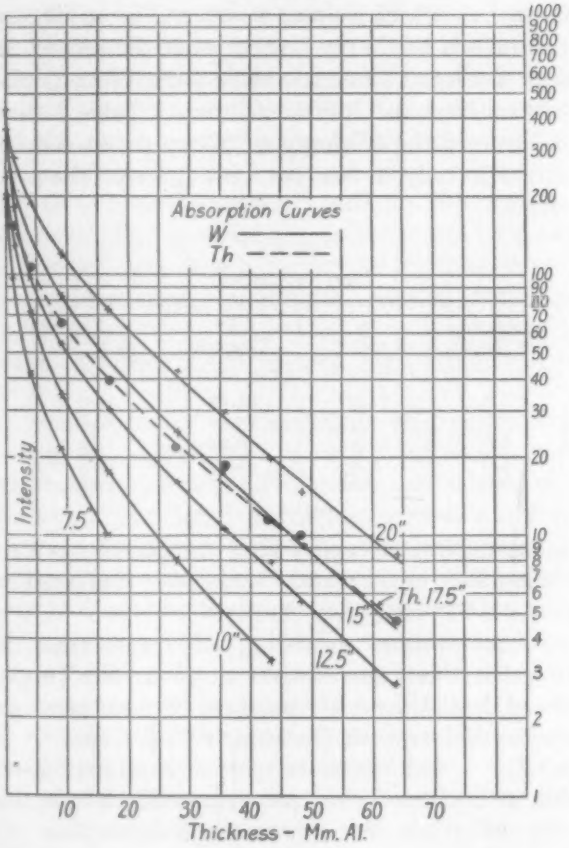
In these experiments the thorium target showed a marked tendency to pit, and hot sparks were continually flying from the

[7] This includes scattering.

focal spot. At the time, this rapid disintegration of the thorium was ascribed to the fact that the metal contained some oxide and had not been mechanically worked. It was, therefore, not as coherent as the wrought tungsten of the companion tube.

More recently Dr. R. W. Moore [8] has succeeded in preparing

FIG. 9.



very pure dense coherent wrought uranium, and targets have been made from this material. In the first tube of this type the uranium button, which was about 1½ mm. thick and 2 cm. in diameter, was held in a four-pointed claw of molybdenum. In this form it was capable of dissipating only the energy correspond-

[8] *Trans. Amer. Electrochem. Soc.*, xliii, pp. 317–328 (1923).

ing to the 0.5 ma. and 225,000 volts (max.) at which it was operated. (The melting point of uranium is only about 1800° C.) The X-ray output of this tube was compared with that of a tungsten target tube operated at the same voltage and current, the X-ray intensity being measured under a copper filter, with an ionization chamber.[9] A transformer with a mechanical rectifying switch was used as a high-voltage source. The results are given in Table I, in which the X-ray intensities in the second and third columns were measured by means of an ionization chamber.

It is evident from the fourth column of Table I that, under the same conditions, the efficiency of X-ray production from the uranium target is only a few per cent. greater than from the tungsten target.

TABLE I.

X-ray Intensities.

Millimetres of Copper.	A Uranium.	B Tungsten.	$\frac{A}{B}$
0.5	24.00	24.10	1.00
1.0	15.93	15.10	1.05
2.0	10.32	8.95	1.14
4.0	5.25	4.65	1.13
8.0	1.84	1.73	1.06

With a one-millimetre copper filter the percentage depth-dose beneath ten centimetres of water[10] was also measured with the same tubes, with the following results:

(1) On machine consisting of transformer and mechanical rectifier, operating at 225,000 volts (max.); percentage depth-dose with tungsten, 18.3 per cent.; percentage depth-dose with uranium, 18.9 per cent.

(2) On continuous-current, constant-potential machine at 200,000 volts; percentage depth-dose with tungsten, 18.9 per cent.; percentage depth-dose with uranium, 19.5 per cent.

From the standpoint of percentage depth-dose, there is, then, but little advantage in uranium over tungsten as a target material.

[9] COOLIDGE and MOORE: *Jour. Radiol.*, Jan., 1924, pp. 9–12.

[10] This quantity, percentage depth-dose under 10 cm. of water, has come into pretty general use by the medical profession in X-ray deep therapy. In this connection, it is, perhaps, easier to interpret than "effective wave-length."

It is interesting to investigate the matter from another standpoint and to question how much greater the intensity would be from uranium than it is from tungsten if, in the case of uranium, only enough filter were used to give the same percentage depth-dose through 10 cm. of water, as in the case of the tungsten target. Calculations from our present rough data would indicate that, at 225,000 volts a.c., the percentage depth-dose through 10 cm. of water, obtained by using a tungsten target and a one-millimetre copper filter, could be duplicated from a uranium target with a 0.75-mm. copper filter, and that the X-ray intensity under the filter, for the same energy input in the tube, would be about one-third greater in the case of the uranium target.

Under certain circumstances, such an increase in efficiency might be interesting, provided a uranium target tube can be made which is in every way as satisfactory as the tungsten target tube.

Because of the energy limitations imposed by the low-melting point of the uranium, a tube having a solid uranium target like that already described could be used for only a relatively feeble X-ray output.

The development of a successful construction for a high-voltage tungsten target with a water-cooled anode made it seem possible to construct also a satisfactory tube with a water-cooled uranium anode. An electric soldering method was developed for attaching sheet uranium to copper by means of a solder consisting of the eutectic alloy of copper and silver. This operation was carried out in a pure hydrogen atmosphere, and the time involved was sufficiently short to prevent any considerable alloying from taking place between the silver and copper of the solder on the one hand, and the uranium on the other. The first uranium button was 1⅜ inches in diameter and 0.032 inch thick, and the focal spot was ⅞ inch in diameter. It seemed likely, from our experience with the water-cooled tungsten target, that the uranium target would be able to handle as much as 50 ma. and 250,000 volts.

Experiment showed that bright sparks were constantly given off from the face of the uranium target, even with as little as 5 or 10 ma. at 200,000 volts, and that the target became rapidly roughened and pitted.

Direct visual inspection indicated that the distribution of energy over the focal spot was extremely uneven and underwent

rapid changes. The uneven heating might have been due to the presence of loose metal particles on the face of the target, but X-ray pin-hole camera pictures of the focal spot indicated that the distribution of energy in the cathode-ray stream was correspondingly uneven and fluctuating in position.

A measurement of the cathode filament-current required for a given milliamperage through the tube indicated that the electron emissivity of the filament was much greater than that of a pure tungsten filament running at the same temperature. Experiment, furthermore, showed that the filament could be returned to its normal condition by heating it to an appreciably higher temperature. The filament had become partly coated with uranium from the anode and had then, in spots, acquired the high electron emissivity of uranium. This had led to the uneven distribution of energy at the focal spot which had then changed as the activated areas on the filament had changed. With such a bad distribution (small areas on the focal spot were very hot), there was evidently a copious supply of uranium vapor to coat the filament. The trouble was probably started by the presence on the target of tiny loose particles of uranium, which were subsequently electrostatically drawn to the cathode.

The fact that the filament could be desensitized, and at a temperature which was not prohibitively high, suggested a remedy for the difficulty which has been tried and found to work. When the filament was kept at a temperature sufficiently high to vaporize any uranium which might deposit on it, and the high-tension voltage was carried to the point required to give the amount of energy which had before caused trouble, the energy distribution was shown, both by direct visual observation and by pin-hole camera pictures, to be much more uniform.

It should be possible to make such a tube to operate satisfactorily at the desired milliampere and voltage by suitably reducing the area of the filament spiral. This would then give the desired milliamperage when operating at or above the temperature required to prevent condensation of uranium on its surface. This method is being tried.

Another method of eliminating the difficulty is also being tested. This consists in designing the cathode so that the current flowing through the tube is limited by space charge rather than by electron emission.

By either of the above methods it should now be possible to construct a satisfactory high-power, high-voltage tube with a uranium target.

In the light of our uranium experience, it now seems probable that the rapid disintegration of the thorium target was likewise due to local activation of the filament spiral by thorium.

The first method for preventing activation by uranium should also apply in the case of thorium or in any other case where the target metal has a lower work function than the material comprising the hot cathode, provided the latter can safely be maintained at a high enough temperature to prevent condensation of target metal upon it.

The method involving the use of a space-charge cathode should also be generally applicable.

E. THE QUESTION OF PRODUCING MUCH SHORTER WAVE-LENGTHS BY THE USE OF STILL HIGHER VOLTAGES.

Voltages much higher than 250,000 can be produced and rectified, if necessary, by kenotrons; the important question is whether tubes can be made which are capable of operation at such voltages. It seems probable that they can when more is known about the suppression of undesired electron emission from those portions of the cathode subjected to high-potential gradient.

It should also prove helpful to study more carefully the effect of the electrical characteristics of the supply circuit on the behavior of the X-ray tube. At the present time, the life of a certain type of high-voltage tube can be made anything from a few minutes to several hundred hours by making changes in the circuit which, from *a priori* reasoning, would seem insignificant. A clear understanding of prejudicial conditions may well lead to the establishment of conditions more favorable to the tube than have yet been realized.

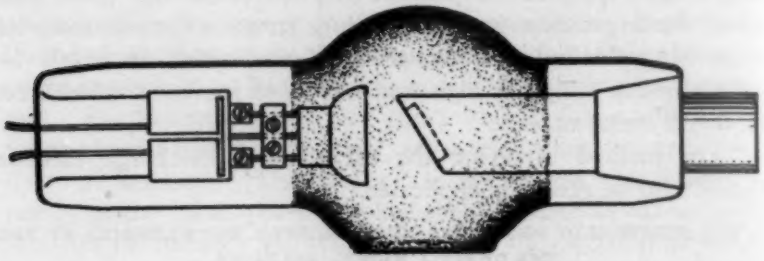
With our present knowledge, tubes cannot be made to operate at as high a voltage when called upon to rectify their own current as they can when used with some auxiliary rectifying device. This applies even with low currents and water-cooled anodes. It is very desirable that we should learn, if possible, how to make tubes behave well at the highest voltages when operating directly from a high-tension transformer, for this knowledge would lead to a simplification in high-voltage X-ray apparatus which would

be especially welcome in connection with attempts to work at voltages much in excess of 250,000.

F. A SMALL X-RAY TUBE FOR USE IN AN OIL-IMMERSED UNIT AND CERTAIN PHYSICAL APPLICATIONS OF SUCH A UNIT.

With the advent of a self-rectifying X-ray tube which is stable and can be made very small, it became interesting to mount the

FIG. 10.

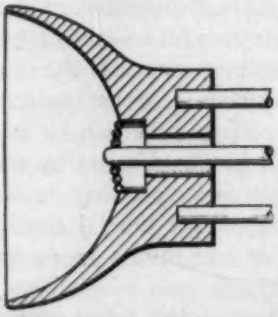


Tube for oil immersion, full size.

tube inside of the same metal tank and in the same oil with the transformer, making the latter as small as possible.

Owing to the enclosure of the whole high-tension system in

FIG. 11.



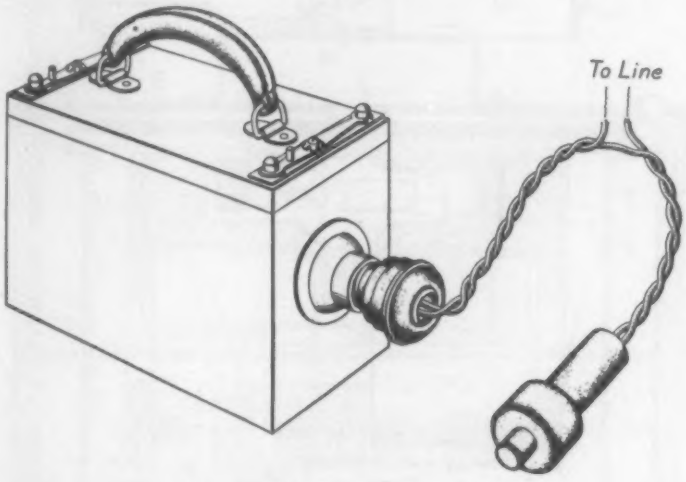
Enlarged cross-section of cathode of tube shown in Fig. 10.

the metallic container, and to the grounding of the latter, there is, with this system, no external electrostatic field. This eliminates the danger of electrical shock and is an advantage in some experimental work where the effect of X-rays might otherwise be masked by the presence of the electrical field of the high-tension circuit. This type of apparatus also permits a very close approach

to the focal spot and, hence, to a region of very high X-ray intensity. Other advantages are to be found in the mechanical ruggedness of the apparatus and in the simplicity of its operation.

Fig. 10 gives a full-sized view of the tube and Fig. 11 an enlarged cross-section of the cathode. With the small focussing device, the focal spot would be too small were it not for the molybdenum pin which projects through the centre of the filament spiral. In oil, the tube operates at 56,000 volts (max.) and 10 milliamperes. The bulb, the stippled portion in the figure, is made of glass

FIG. 12.



Complete oil-immersed unit.

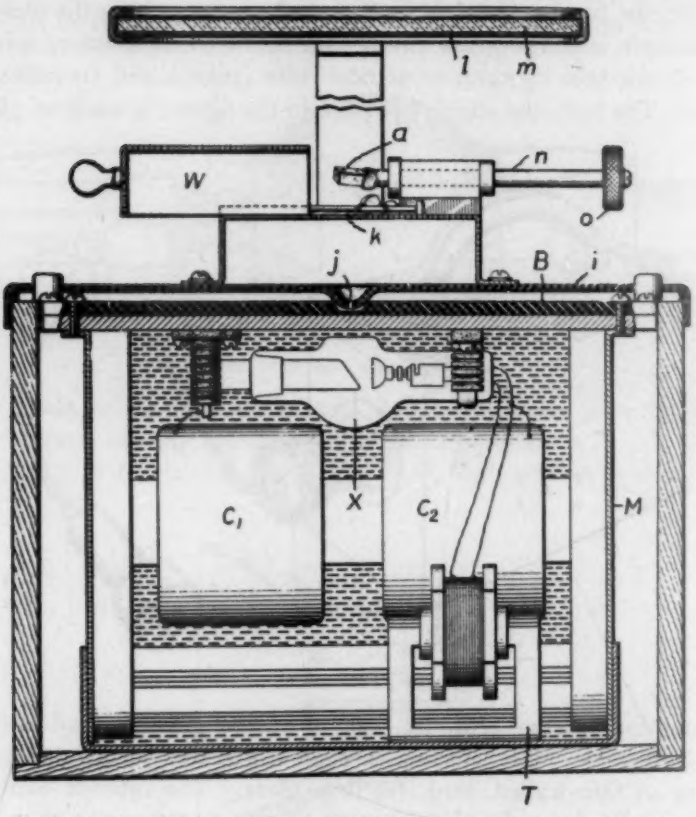
containing 55 per cent. by weight of the element lead and is ⅛ inch thick. The window through which the X-rays emerge is made of thin-walled, lead-free lime glass. The cathode filament spiral calls for a heating current of 2.2 amperes at 2.6 volts. The low filament wattage involved, 5.7 watts, permits of the use of a very small filament transformer.

The complete oil-immersed unit is shown in Fig. 12 and, with an added attachment, in vertical section in Fig. 13. In the latter figure, the tube is seen mounted directly over the high-tension coils, C_1 and C_2, of the X-ray transformer. T is the filament transformer. M is the metal container in which the unit is mounted and B is a bakelite cover to which the unit is attached.

By means of a suitable gasket, the cover joint is made tight and the container is filled full of oil.

The unit is described in much greater detail in an article to appear soon in the *Journal of the Optical Society of America.*

FIG. 13.



Vertical section of oil-immersed unit arranged for fluoroscopic demonstration of Laue diffraction experiment.

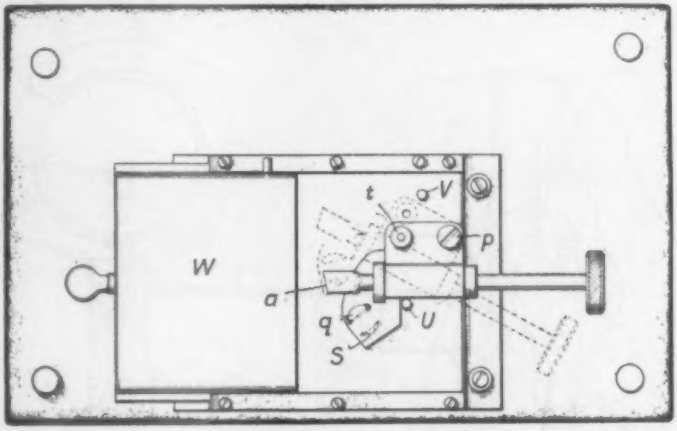
The following illustrations will serve to show the usefulness of the device in physical demonstrations.

A. Diffraction of X-rays.—With the device arranged as in Figs. 13 and 14, the Laue experiment can be shown fluoroscopically. For this set-up, the cover of the outfit shown in Fig. 12 has been replaced by a metal plate, *i*, in the small depressed portion of which is an opening, *j*, 0.067″ in diameter. This dia-

phragm, together with a second one, *k*, having an opening of the same size and mounted 1⅜″ above the first, serves to define a small beam of X-rays which passes upward to the fluoroscopic screen, *l*.[11] The observer is protected by the lead glass, *m*.

With the apparatus as shown, a rock-salt crystal, *a*, cemented to the end of a rotable shaft, *n*, is in the path of the X-ray beam. As the rock-salt crystal is rotated by means of the knurled head,

FIG. 14.



Plan view corresponding to Fig. 13.

o, the diffraction pattern, seen on the fluoroscopic screen, shifts, while the primary beam remains fixed in position.

The plate on which the rotatable rock-salt crystal is mounted is pivoted on a vertical axis at *p* and carries two other crystal fragments, one of sapphire at *q* and one of diamond at *s*. The dotted position shows the crystal, *s*, in the path of the X-rays, and a position intermediate between the solid and dotted positions brings the crystal, *q*, into the beam.

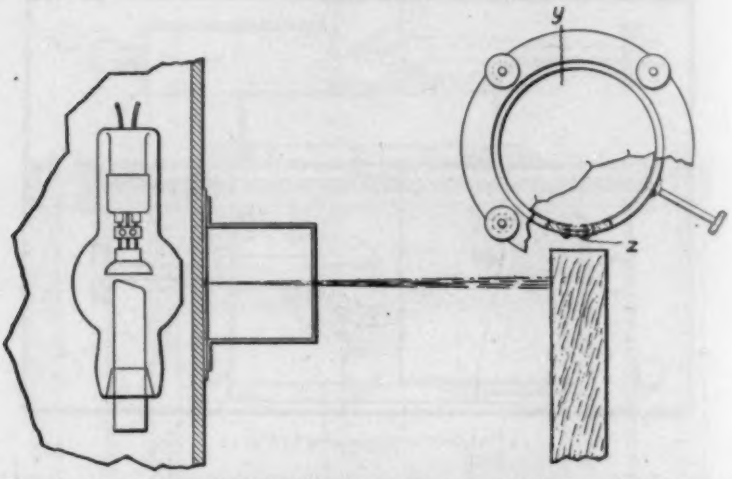
Through the agency of a small spring actuated pin, *t*, which engages with two depressions in the plate below, and two stops, *u* and *v*, the crystal-carrying member is given four definite positions, one for each of the crystals and one in which there is nothing interposed in the path of the rays.

[11] The most sensitive fluoroscopic screen available should be used for this purpose. That made by the Patterson Screen Co., of Towanda, Pa., has been found suitable.

W is a metal cover which can be slid over the crystal-carrying member, for mechanical protection, when the outfit is not in use.

B. Ray-track Experiment.—For use with the C. T. R. Wilson apparatus, as modified by Shimizu,[12] the X-ray outfit is provided with a special metal cover carrying two diaphragms, and is so placed (Fig. 15) that the small X-ray beam defined by these diaphragms passes about an inch to one side of the expansion chamber, *y*. A circular window, *z*, of aluminum foil 0.0025 inch

FIG. 15.



Plan view of unit arranged to show X-ray scattering by means of ray track apparatus.

thick and ⅜ inch in diameter, is clamped at the periphery between two brass rings and these are fastened with Khotinsky cement in a hole drilled in the glass side-wall of the expansion chamber.

When the X-ray switch is closed, no clouds are seen in the chamber unless some scattering material is interposed in the X-ray beam opposite the aluminum window, in which case scattered radiation can enter the expansion chamber.

When a piece of wood is used as the scattering agent, the clouds in the ray-track apparatus appear to have an average length of perhaps a centimetre, while if copper is used, most of the clouds appear to be about 2 millimetres long. The difference is very apparent and the short clouds are due to the K-radiation from the copper.

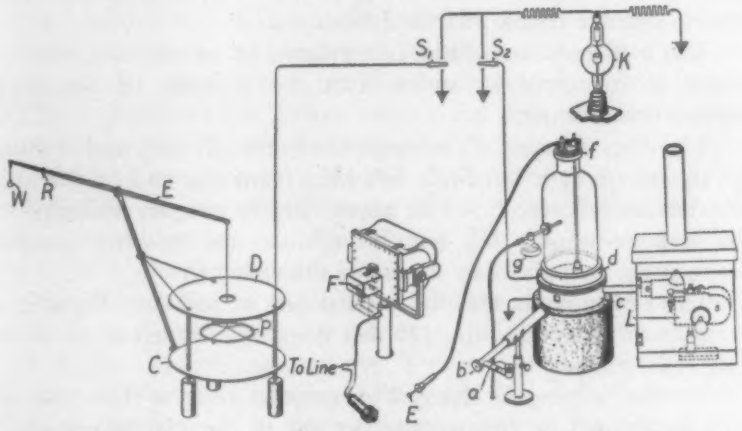
[12] SHIMIZU, T.: *Roy. Soc. Proc.*, **99**, pp. 425–431, Aug. 2, 1921.

C. The Millikan Oil-drop Experiment and a Working Model of the Same.—In Fig. 16 an X-ray unit is shown in the centre with the Millikan oil-drop apparatus to the right and the model to the left.

The oil-drop apparatus is essentially as described by Millikan.[13] A second demonstration eye-piece has been added to the telescope. The second observer uses the eye-piece, *a*, while the demonstrator uses the other eye-piece, *b*.

Pressure on *E* uncovers the hole in the upper plate, *d*, of the

FIG. 16.



Perspective view of X-ray unit arranged to demonstrate Millikan oil-drop experiment and to operate a working model of the same.

oil-drop chamber, and, at the same time, closes a hole in the stopper, *f;* compressed air is admitted to the atomizer, *g*, through a valve which is not shown.

The self-feeding arc-lamp, *L*, is placed in a light-tight housing, provided with ventilating lœuvres.

The room is effectively darkened.

High-voltage direct current is obtained from a transformer, not shown, and kenotron, *K*. A high resistance unit, shown to the left of *K*, is used as a safety device to limit the current which can be drawn from the transformer and a similar unit, to the right, lets the potential of the high-tension circuit fall as the primary voltage of the transformer is lowered.

[13] MILLIKAN, R. A.: *Phys. Rev.*, **32**, pp. 349–397 (1911).

The X-ray unit is supported by a vertical rod which passes through the top of the table and is counter-weighted so that it can be easily raised and lowered. It is also easily rotatable about the vertical axis.

No attempts have been made to do quantitative work with this apparatus, but it has been used with great satisfaction for showing the qualitative side of the Millikan experiment.

The working model of the experiment is seen to the left of the X-ray outfit in Fig. 16. The large metal plates, C and D, correspond to the plates, c and d, of the Millikan apparatus. C is, like c, connected to ground, while, by means of S_1 and S_2, the high-tension current can be switched from d to D.

The high-tension voltage is regulated by means of a rheostat which is connected in series with the primary of the high-tension transformer.

The disc of paper, P, corresponds to the oil-drop and is hung, by a piece of light oiled-silk fish line, from one end of the light wooden scale-beam, E. The paper disc is roughly balanced by the counter-weight, W, and brought to the midway position between the two plates by means of the rider, R.

The experiments may be carried out as follows: Plate D is brought to +10,000 volts. If this does not disturb P, it shows that P is uncharged.

If now, leaving D charged to +10,000 volts, a thin beam of X-rays, defined by the rectangular slit in the diaphragm, F, is passed through the air below P, the latter quickly rises, showing that it has acquired a negative charge.

If the voltage of D is reduced to zero, P returns to its original position, moving upward again, however, if D is again brought to +10,000 volts.

The negative charge may next be removed from P by bringing D to zero potential and then, with diaphragm, F, dropped down, as shown in the dotted position, turning a large beam of X-rays on P and the surrounding air.

That the charge has been removed is shown by the fact that, upon now bringing D to + 10,000 volts, P does not move.

If now, using the rectangular diaphragm, and with D at +10,000 volts, a thin beam of X-rays is passed through the air above P, it is seen that P moves downward, showing that it has acquired a positive charge.

The behavior of the piece of paper is then like that of the oil-drop. It can, at will, be made either to acquire or to lose electrons.

The experiment also has this to recommend it, that, unlike many static experiments, it works as well in wet weather as in dry.

D. Thermoluminescence.—If the lead cover is removed from the unit, shown in Fig. 13, and a piece of fused quartz is held for a couple of seconds in the X-ray beam close to the window of the unit and then subsequently heated in the dark in the flame from a Bunsen burner, it will be seen that, long before becoming visibly red, it gives off a bright blue light.

If a strip of the ordinary calcium-tungstate intensifying screen, say an inch wide, is held, with a pair of tongs, in the X-ray beam close to the window of the X-ray outfit, there appears, in a darkened room, a brilliant blue luminescence. Upon removing the screen from the X-rays, there is but little phosphorescence. If now the screen is brought to liquid air temperature by immersing it for a moment in a Dewar flask filled with liquid air, and is then quickly placed in the X-ray beam for a few seconds, there appears, as the screen warms up, a brilliant green thermoluminescence.

This experiment is much more beautiful if a platino-cyanide of barium screen is used. In this case, the screen gives off green light under the influence of the X-rays and shows very little phosphorescence. If immersed in liquid air and then quickly subjected to X-rays, it shows, upon warming up, six distinct luminescent periods, taking place in the following order: Green, light yellowish green, reddish brown, light green, light reddish brown, darker reddish brown.

G. GENERAL SUMMARY.

The foregoing consists in the main of a discussion of some of the physical principles involved in the hot-cathode ("Coolidge") type of X-ray tube and deals with the factors which most strongly influence the characteristics and behavior of such tubes.

For the production of short wave-length X-rays, tubes are now made to operate satisfactorily at voltages up to 250,000 (max.). Voltages greatly in excess of this are now available and the high-voltage currents can, if necessary, be rectified by kenotrons. The question of whether much shorter X-ray wave-

lengths can in this way be produced resolves itself into the question of whether X-ray tubes can be made which will be capable of operation at such high voltages. The main problem to be solved in this connection is that of preventing undesired electron emission from those portions of the cathode structure which are subjected to high-potential gradients. The study of this problem is not completed, but is encouraging.

Effective wave-length can be somewhat reduced by the substitution of thorium or uranium for the tungsten of the usual target. In the attempt to make tubes, with such targets, capable of giving a high X-ray output, the following serious difficulty has been encountered: Some of the target metal finds its way to the hot cathode where it produces areas of abnormally high electron emission and these give rise to a very uneven and rapidly changing distribution of energy over the focal area, thus seriously limiting the allowable energy input of the tube. If the cathode is operated at a sufficiently high temperature, it has been found that the condensation of target-metal vapor upon it is prevented and the troublesome uneven distribution of energy on the focal spot is avoided. Another method of obviating the difficulty consists in designing the cathode so that the current flowing through the tube is limited by space charge rather than by electron emission. By either of the above methods it should now be possible to construct a satisfactory high-power high-voltage tube having a water-cooled target of thorium or uranium, and this work is well under way.

For the use of the dentist, a very small X-ray tube has been developed to operate in the same oil and in the same metallic container as a high-tension transformer. The resulting X-ray generating unit, with its compactness, ease of manipulation, and freedom from external electrostatic field, seems especially well adapted to some lines of physical investigation work and to various physical demonstrations, making it easy, for example, to show the Laue diffraction experiment fluoroscopically.

THE FYNN-WEICHSEL MOTOR.*

A POWER-FACTOR CORRECTIVE FOR ALTERNATING-CURRENT DISTRIBUTION SYSTEMS.

BY

HANS WEICHSEL.

The Wagner Electric Corporation, St. Louis.

IN any alternating or polyphase system, two kinds of current are flowing:

(1) The so-called watt or working current;

(2) The so-called wattless or magnetizing current.

The working current is the current which is transformed into mechanical energy in the motor, or which in heating apparatus is transformed into heat. In other words, it is the current which is transformed into useful energy in the current-consuming device.

The second mentioned current, the wattless or magnetizing current, does not do any useful work, but produces the necessary magnetic lines for operating the power-consuming device. For instance, in transformers and motors, this current produces the magnetic lines necessary for driving the current through the secondary windings of these pieces of apparatus.

Any current, whether magnetizing or watt current, when sent through a wire, consumes power. The power loss is proportional to the square of the current multiplied by the resistance. Therefore, if a circuit has a resistance of R ohms and a working or watt current I_w is flowing, the current produces a loss of $P_c = (I_w)^2 \times R$. In the same manner, if a magnetizing current, I_m, is flowing through the same wire with the resistance R, it produces a loss of $(I_m)^2 \times R$. The total loss due to both currents will be the sum of the individual losses, *i.e.*, total loss $= (I_w)^2 \times R + (I_m)^2 \times R$.

While these two individual currents are flowing in a wire, an ampere meter placed in the circuit indicates one current only, which is the combination of the working and magnetizing currents. Electrically speaking these currents are 90 electrical degrees phase-displaced against each other and, therefore, the resultant current is not equal to the arithmetic sum of the indi-

* Presented at a meeting held Thursday, October 30, 1924.

vidual currents, but is equal to the geometric sum, *i.e.*, the resultant current is given by the equation:

$$I = \sqrt{I_w^2 + I_m^2}$$

If, for instance, the working current is equal to the magnetizing current, then the total current as indicated by an ampere meter in the circuit would be $\sqrt{2} \times$ working current. The total current, therefore, would be about 41 per cent. larger than the current needed for the desired work.

The ratio $\frac{\text{working current}}{\text{total current}}$ has been called the "power-factor." In the example, therefore, the power-factor is $\frac{1}{\sqrt{2}} = 71$ per cent. The power-factor is a coefficient which has been used for many years in describing the relations in an alternating-current system. It is, however, very unfortunate that this factor has ever received great publicity, as it really disguises the true issue. It is much more to the point to form a coefficient between the magnetizing and the working currents. In the example, for instance, the magnetizing current is equal to the working current, and the coefficient $\frac{\text{magnetizing current}}{\text{working current}}$, which we will call "magnetizing factor," is unity. For an installation with 40 per cent. power-factor, the "magnetizing factor" is 2.3×. That means an installation with 40 per cent. power-factor takes a magnetizing current of 2.3 × the useful or working current.

Fig. 1 represents the relation between the power-factor and magnetizing factor. This illustration shows the enormous values of magnetizing currents which must be transmitted through the wiring when the power-factors of the systems are low. From what has just been stated, it is clear that the magnetizing current in a system results in the following:

First, for a given circuit and a given power transmission, the energy loss in the system is considerably larger than it would be if the magnetizing current were zero, corresponding to a unity power-factor.

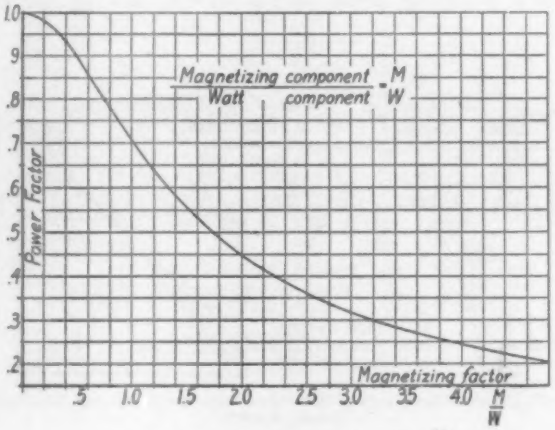
Second, if, with poor power-factor or large magnetizing current, the losses in a circuit could be kept at the same value as in the circuit, operating with unity power-factor, then the necessary amount of copper and, therefore, investment would be considerably larger than for the ideal case of unity power-factor.

Third, a system with poor power-factor or large magnetizing current requires larger generating units to produce the necessary energy and also all switches and transformers in the circuit must be increased in capacity, because the size of these parts of the apparatus depends on the current and not on the energy.

Fourth, low power-factor results in poor voltage regulation, with consequent increased losses, in the system.

The financial losses due to either additional copper losses or investment caused by poor power-factor or large magnetizing

FIG. 1.



Power factor as a function of the ratio $\frac{M}{W}$.

factor are tremendous. Even engineers well versed in this subject of power-factor were greatly surprised by the results obtained from an estimate of the excess capital investment due to the power-factor in present electric distribution systems. It has been conservatively estimated that this loss amounts to about one and one-quarter billion dollars. It is not astonishing, therefore, that a great many power companies have arranged their rates in such a manner that the customer maintaining unity power-factor enjoys the minimum rate with an increasing rate with decreasing power-factor.

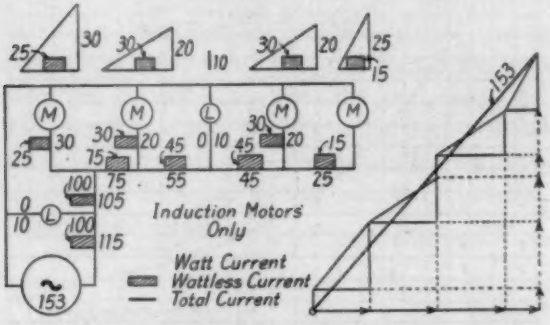
The Technical Committee of the National Electric Light Association realized that the poor power-factor in the present systems is to a very large extent the result of the universal application of induction motors.

The induction motor, while an excellent power machine, has the unsatisfactory characteristic of drawing a rather large magnetizing current. The magnetizing current in these machines under load is frequently equal to the working current or even larger.

The 1921 Convention of the N.E.L.A. passed a resolution calling this serious motor defect to the attention of the motor manufacturers and consequently the Apparatus Committee of the association sent an urgent letter to the motor manufacturers of the country asking what could be done and when central station relief could be expected.

The very pressing need for a motor having all the good

FIG. 2.



Schematic diagram showing working current, wattless current and total current in an a.c. system.

characteristics of the now so universally used induction motor, but which at the same time is free from the very undesirable characteristic of lagging magnetizing current, is therefore evident.

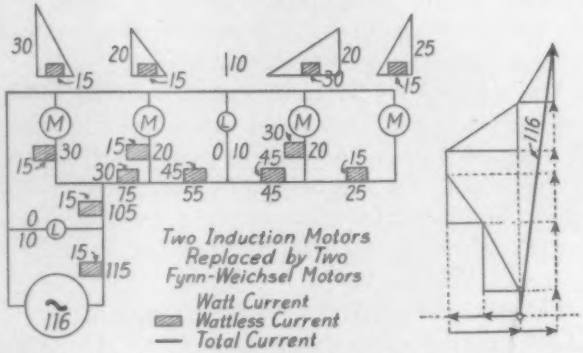
For very many years it has been known to electrical engineers that the so-called synchronous motor has the ability to operate with unity power-factor, *i.e.*, without drawing magnetizing current from the line. If desired this type of machine can even be operated with leading power-factor, *i.e.*, the machine takes a negative magnetizing current from the line.

If such a machine is adjusted for leading power-factor, *i.e.*, negative magnetizing current, and is operated in parallel with an installation consisting of standard induction motors, then the negative magnetizing current of the synchronous motor subtracts from the positive magnetizing current of the induction motor with the result that the total magnetizing current taken from the

line is zero or materially reduced, depending upon the relative magnitude of the negative magnetizing current of the synchronous motor and the positive magnetizing current of the induction motor.

Fig. 2 shows an installation consisting of induction motors and lamps. The unshaded figures represent the working current taken by the individual units. The shaded figures represent the magnetizing currents taken by the individual units. All working currents (unshaded) add arithmetically, and all magnetizing currents (shaded) add arithmetically, with the result that the

FIG. 3.



Schematic diagram showing working current, wattless current and total current in an a.c. system.

generator has to supply a working current of 115 amperes and a magnetizing current of 100 amperes.

If some of these induction motors are removed and are replaced by synchronous motors which are so adjusted as to draw negative magnetizing current, then the distribution of the currents in this system is given in Fig. 3. Again the working currents are represented by the unshaded figures, and add in the same manner as before. The magnetizing currents are again shown by the shaded figures, but it will be noticed that the magnetizing currents of the synchronous motors now subtract from the magnetizing current of the induction motors with the result that in this particular example the total magnetizing current to be supplied by the generator has been reduced to a value of only 15 amperes.

While the synchronous motor which has been known for many years has the admirable characteristic of being able to supply lead-

ing magnetizing currents, this motor has found only a rather limited field of application, due to the many shortcomings in its other characteristics. The most pertinent disadvantages in the characteristics of the old type of synchronous motor are:

(1) It has an extremely poor starting characteristic. It takes a very large current to produce a reasonably large starting torque. If an attempt is made to reduce the starting current to reasonable limits, the motor develops another bad characteristic, *i.e.*, the inability of reaching under load a speed sufficiently high to operate as a synchronous motor, and if this is the case it will operate as an induction machine. Due to the inherent design characteristics of this type of synchronous motor, it makes a very poor induction machine. It draws a very large magnetizing current when operating as induction machine.

(2) The type of synchronous motor referred to above falls out of step when loaded beyond a certain point. That means, when the machine is loaded beyond, let us say, 150 per cent. to 200 per cent., depending on the design of the machine, it suddenly comes to rest and draws an excessive large current from the line, which usually results in blowing the fuses or opening the automatic protecting devices.

(3) The machine requires a separate supply of direct current, which must either be taken from a separate d.c. system or be generated by a separate exciter.

With these shortcomings inherent to the old type of synchronous motor, it is readily seen that its field of usefulness is rather restricted and that, therefore, it cannot be used as a general power motor; and for this reason, this type of synchronous motor cannot contribute materially to the solution of the power-factor problem which confronts the electrical industry.

The most effective element toward the solution of the power-factor problem lies, therefore, in a motor which has all the good characteristics of the present induction motor and in addition to this the good characteristics of leading power-factor or negative magnetizing current of the synchronous motor.

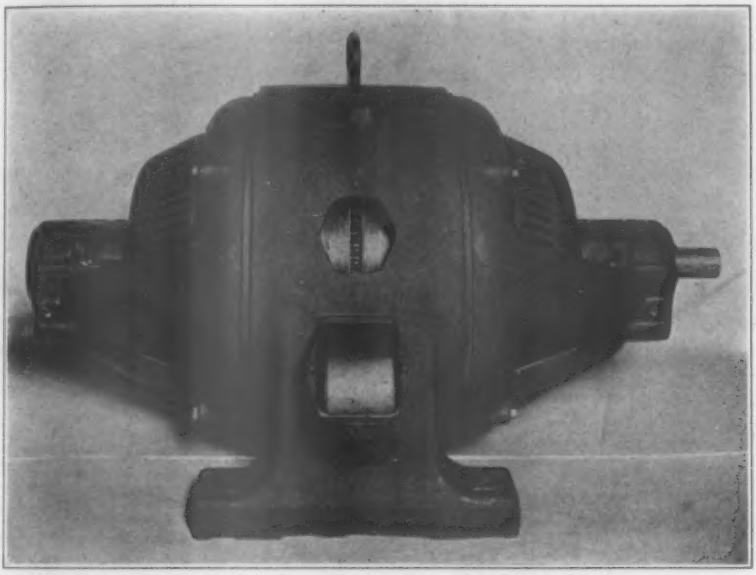
This situation in the electrical industry has a parallel in the problem which existed approximately twenty-five years ago, when the engineers realized the great advantages in the use of single-phase alternating-current distribution systems. It was impossible at that time to make full use of this knowledge because there

existed no single-phase motor which had good running and starting characteristics.

The so-called split-phase motor was known, but while this motor had satisfactory running performance, it had an entirely unsatisfactory starting performance.

At that time, there was developed in response to this great need the single-phase repulsion-starting induction-running motor,

FIG. 4.



which had good starting performance and a running performance as good as the best split-phase motor.

The accomplishment of this motor was considered by The Franklin Institute as a meritorious achievement, and the Institute granted the Longstreth Medal for this machine in the year 1902.

To-day the industry is confronted by a much greater problem, which can be best solved by the creation of a new type of motor.

It is with the design and development of such a motor, known under the name Fynn-Weichsel Motor, that this paper attempts to deal.

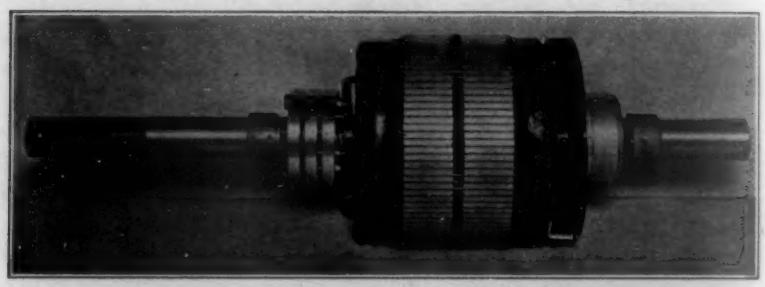
This machine has a running performance better than that of a standard synchronous motor, has starting performance as good as the best type of induction motor, and has further an admirable

ability to synchronize automatically when going from starting to running operation.

This new type of machine, in its general construction, does not differ materially from the construction used for many years in standard induction motors.

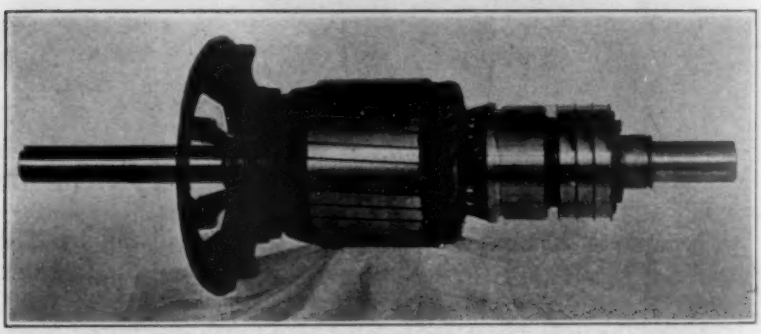
Fig. 4 gives the general view of a 100-hp. Fynn-Weichsel

FIG. 5.



motor. The machine has slip rings similar to a standard induction motor with wound armature and in addition to this has a relatively small commutator. The slip rings and commutators are

FIG. 6.



located below the covers which are shown on each side of the machine.

Fig. 5 shows the general appearance of the rotor of the machine just shown. The slip rings are on one side and the commutator on the other side of the rotor. This construction is generally used in the large units. In the small units, the commutator and slip rings are located on the same side of the rotor,

as shown in Fig. 6, which represents an armature of a 15-hp., 1800 r.p.m. machine.

In all of these machines, the rotors are built of laminated iron, which is provided with slots on the circumference, in the same manner as in standard induction motors. In the bottom of these slots is located a very small d.c. winding which is connected to the

FIG. 7.

commutator. This small d.c. winding generates a relatively low-voltage direct current for the excitation of the field when operating as a synchronous machine.

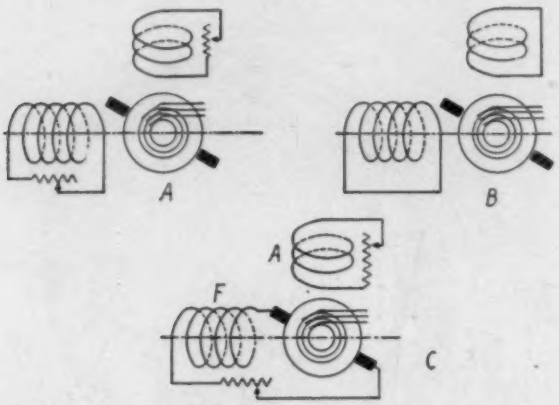
The largest part of the slots is filled with a winding which is connected to three slip rings. This winding is in every respect a standard polyphase winding. The slip rings are connected by brushes to the supply circuit.

Fig. 7 shows the stator of a 100-hp. unit. The stator is built

of laminated iron with slots all around the inside circumference, in exactly the same manner as in a standard polyphase induction motor.

The stator carries two independent windings which are 90 electrical degrees displaced from each other. Electrically speaking, the stator winding is very similar to a standard two-phase winding. Mechanically, however, this winding is considerably simpler than a standard two-phase winding, because it is of the so-called concentric type, which is the simplest winding known.

FIG. 8.



Starting connections.

In standard induction motors usually the more complicated so-called diamond winding is made use of.

This concentric winding used in the stator of the Fynn-Weichsel motor has, besides its simplicity, the advantage of offering less ohmic resistance for a given number of ampere turns and slot area than can be obtained with the diamond winding. In other words, the losses in this style of winding will be less than in diamond windings.

Having now described in general the construction of this machine, it is necessary to explain how the different windings in this machine are interconnected and are electrically related to each other.

Fig. 8 illustrates different ways of connecting the machine during starting. *A* shows the machine connected in the same manner as a standard slip-ring induction motor, *i.e.*, during the

starting period resistance is connected across the two secondary windings. The value of the resistance is so selected as to give the machine the desired starting torque. By decreasing these resistances the machine obtains for a given required mechanical torque a higher speed, and finally when these resistances are short-circuited, the machine operates as a standard induction motor. If, at this time, the commuted winding of the rotor is connected in series with the winding *F* on the stator, the machine automatically increases its speed until it transforms itself into a synchronous machine.

This connection, while quite feasible, is desirable only for fairly large units. For medium and small sizes, it is possible to start the machine with the commutator winding permanently connected in series with the stator winding *F*. The connections are then as given in *C*. Resistances are connected in series with the *F* as well as with the *A* circuit. By decreasing the value of these resistances, the machine increases in speed until finally, when these resistances are short-circuited, the machine automatically transforms itself into a synchronous machine. This synchronization takes place with a powerful torque and without excessive current draw from the line.

The physical phenomena which cause the easy synchronization of this machine will be understood from the following:

If an induction motor runs fully loaded, the rotor operates with a speed slightly below the speed of the revolving field. This speed difference induces an e.m.f. of such a magnitude in the secondary winding as to produce a current just large enough to develop a torque—by interaction with the revolving field—which is equal and opposed to the mechanical useful torque which the motor has to overcome. If it is possible to increase the current in the secondary at this speed, then an excess of motor torque exists and results in speeding up the motor, because its torque is larger than the torque required for the useful load.

In order to accomplish this increase in current, it is simply necessary to have an e.m.f. acting on the secondary winding or windings which is larger than the e.m.f. induced in this winding due to the slip of the machine. Naturally this e.m.f. must have the same frequency and preferably the same phase relation as the e.m.f. induced by the slip of the machine.

If, for instance, the slip of the motor is 5 per cent. and the line frequency is 60 cycle, then the voltage induced in the secondary windings has the frequency 5 per cent. × 60 = 3 cycle. Assuming that this voltage has a magnitude of five volts, and that in some manner there is injected in this circuit an additional two volts with a 3-cycle frequency, then a total voltage of seven volts is acting on the secondary circuit and the current increases in the relation of $\frac{7}{5}$. Therefore, the slip of the machine approximately decreases in the ratio $\frac{5}{7}$.

By properly selecting the injected voltage, it is possible to decrease the slip of the motor when running as an induction machine to such a value that it will operate very nearly at synchronism and, therefore, can automatically synchronize.

The necessary injected low-frequency voltage is, in this new type of machine, generated in the simplest manner. The armature, as pointed out in the beginning, carries in addition to the main working a.c. winding a small commuted winding. The line voltage impressed on the slip rings produces a rotating magnetic field which revolves with a definite speed in respect to the armature conductors. In a 4-pole, 60-cycle machine, this speed would be 1800 r.p.m. From the laws of induction, it is known that if this machine is allowed to operate as a motor, the armature must rotate in a direction opposite to that of the revolving field. Therefore, with increasing armature speed, the speed of the revolving field in respect to a fixed point in space will decrease, and when the armature rotates at synchronous speed the field revolving in respect to the armature conductors is stationary in respect to a fixed point in space.

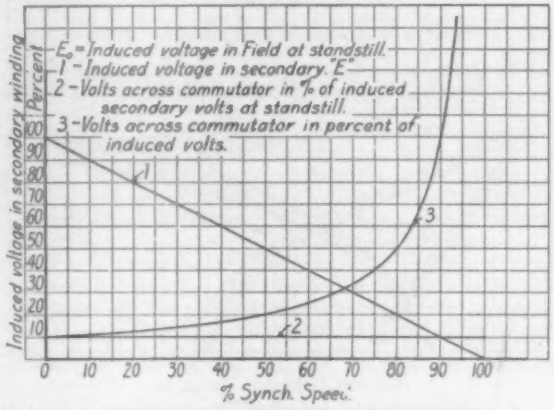
There is, however, a fundamental law that the frequency of the voltage appearing across the brushes of a commuted winding is proportional to the relative speed of the field producing this voltage in respect to the brushes. If this speed is zero, the voltage across the brushes is of zero frequency, *i.e.*, a d.c. voltage. If the field rotates against the brushes with a velocity corresponding to f_2 cycles, then the frequency across the brushes is f_2.

In other words, the frequency appearing across the brushes of this new machine at any time is proportional to the frequency with which the field of the machine rotates in respect to the brushes; but this is the same frequency with which the field

rotates in respect to the secondary windings. Therefore, the frequency of the voltage appearing across the commutator brushes is at any time equal to the frequency induced in the secondary winding.

A similar train of thought will lead to the conclusion that the voltage appearing across the commutator brushes is in phase with the voltage induced in the secondary when the brush axis coincides with the axis of this secondary winding. Therefore, if the commuted winding is connected in series with this second-

FIG. 9.



Open-circuit voltage in secondary winding and across commutator.

ary winding, the total voltage acting on this circuit is increased above the value which exists in this secondary winding due to the induction only. By properly selecting the magnitude of this injected voltage from the commutator, it is possible to increase the speed of the machine to such a value that it readily synchronizes.

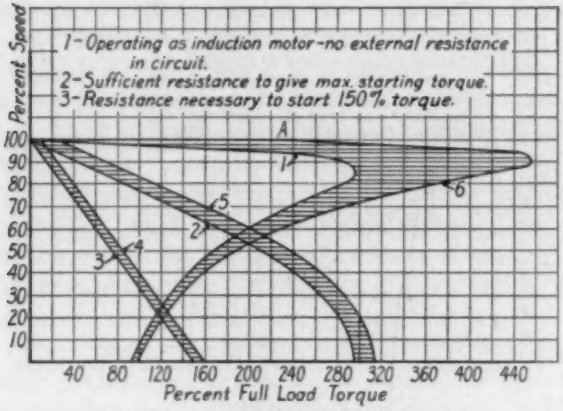
A further study of the voltage across the commutator shows that this voltage is of fixed magnitude, *i.e.*, independent of the armature speed, because the velocity of the magnetic field in respect to the armature conductors is in no manner depending on the speed of the armature itself.

It is a well-known fact, however, that the voltage induced in the secondary of an induction motor decreases with increasing speed. Therefore, the ratio $\frac{\text{injected voltage}}{\text{induced voltage}}$ increases rapidly

with increasing speed. This has been shown in Fig. 9. The influence of the injected voltage on the speed of the machine is, therefore, self-accumulating, and becomes larger and larger the nearer the machine comes to synchronous speed.

This can be seen from the curves 1, 2, and 3, in Fig. 10, which show the speed torque curves of this type of machine when operating as a straight induction motor with different amounts of resistance in the secondary. The curves 4, 5, and 6 show the speed torque curves of the machine with the same resistance in

FIG. 10.



Speed torque curves of Fynn-Weichsel motor.

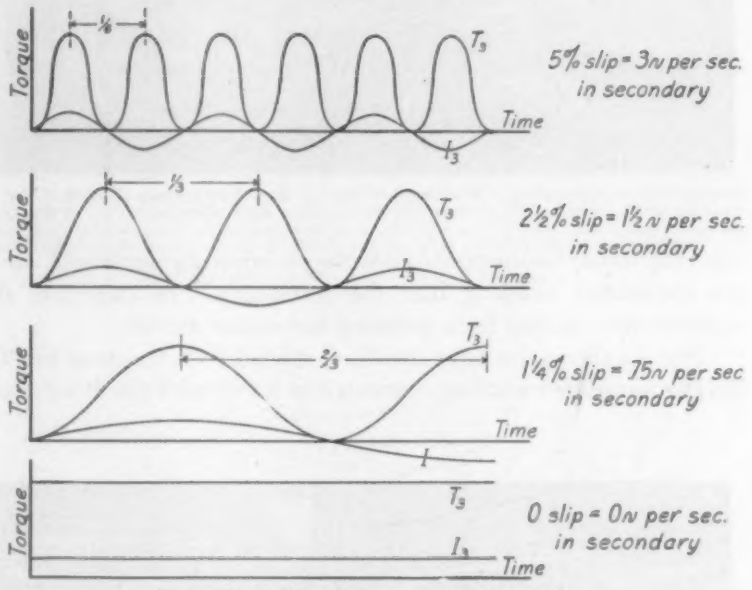
the secondary circuit, but with an injected e.m.f. induced in the *F* winding by connecting this winding in series with the commuted winding.

The shaded parts of these curves show the increase in the torque of the machine due to the injected e.m.f. for a given speed. A further detailed study of the characteristics of this additional torque shows that it is of a pulsating nature and the pulsations become slower and slower as the machine approaches synchronous speed. This can readily be appreciated if it is remembered that this additional torque is produced by the injected low-frequency voltage. At the moment when this injected voltage is zero, it cannot produce any additional torque, and the moment when the additional voltage has its maximum, the additional torque must be a maximum. Therefore, the torque will have as many maxima in a second as the injected current has during the same time.

The change in torque, for four different speeds of the armature, as function of time, is given in Fig. 11. These curves show that the pulsation of the torque becomes slower and slower with increasing speed and finally the pulsation becomes zero and the torque, therefore, becomes constant. This condition exists when the machine operates at synchronism.

The injected voltage is in phase with the induced voltage when the brush axis coincides with the field axis, which means the best

FIG. 11.



Torque due to injected current as a function of slip.

synchronizing conditions are obtained when these two axes coincide. For reasons to be shown later, it is, however, preferable to have a relatively small angular displacement between these two axes, but a little study of the phenomena will show that a relatively small angular displacement between the brush axis and the axis of the secondary winding does not decrease appreciably the synchronizing ability of the motor.

Machines as regularly designed are so dimensioned that they readily synchronize with a mechanical load of 150 to 200 per cent. of their normal rating.

Oscillogram studies of the very interesting starting period of

these machines will be instructive and are given in the following figures:

Fig. 12 shows the line current and the secondary current in this type of machine when started and operated as a straight

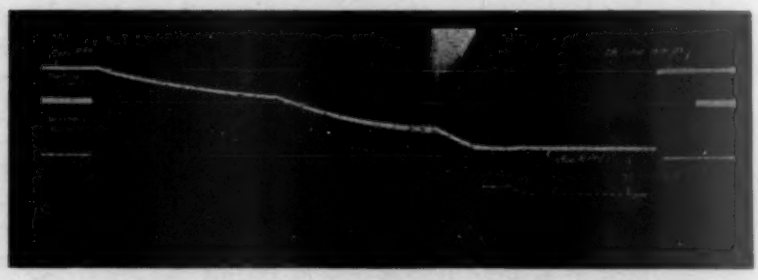
FIG. 12.

Starting full-load torques as induction motor. | Brushes raised and short-circuited. | Secondary amps. Main phase. | Length of film = 9 sec.

slip-ring induction motor, *i.e.*, without injecting the e.m.f. from the commuted winding into the secondary. In this case the machine was started by a one-step automatic starter.

Fig. 13 shows the same machine, started with the same starter, but the commuted winding connected in series with the F winding.

FIG. 13.

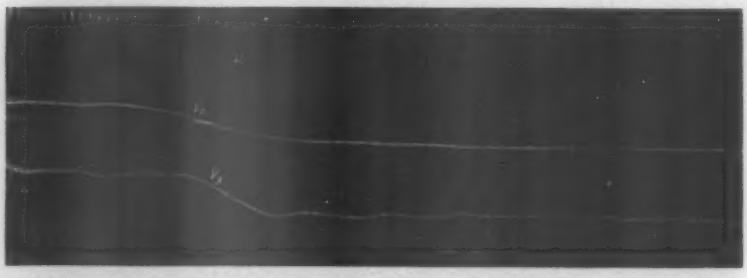


Starting full-load torque, i. c. control. Length of film = 9 sec.

It will be seen that the secondary current in this case decreases with increasing speed of the machine in exactly the same manner as in the first oscillogram. However, in the first oscillogram the frequency of the secondary current never decreased below a certain value (approximately two cycles per second), while in this

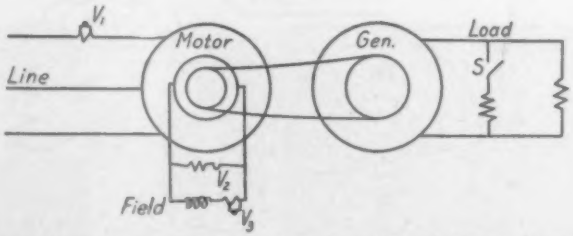
diagram it is seen that the frequency decreases to zero, *i.e.*, the current goes over into a direct current. When the secondary frequency changes to direct current, the machine synchronizes itself. The primary current draw is also given on this oscillogram, and it will be noticed that, generally speaking, it is about

FIG. 14*a*.



V_1—Current on motor circuit when the motor returns to synchronous operation when load is reduced to 150 per cent. In other words this curve shows the current performance when the motor pulls back into step as the load is reduced from over 200 per cent. (induction) to 150 per cent. or less (synchronous). Note the steady current wave under synchronous operation.
V_2—Direct current field voltage when motor pulls back into step.
V_3—Direct current field amperage when motor pulls back into step.

FIG. 14*b*.



Induction to synchronous operation on 15-hp. Fynn-Weichsel motor. Induct. imput = 37.5 hp. at 0.91 p. f. lagging. Syn. imput = 26 hp. at unity p. f. V_1 = line I = 80 amperes, initial. V_2 = field voltage = 14.8 volts. V_3 = field I = 40 amperes.

equal to the current draw shown on the oscillogram in Fig. 12, which shows the machine starting as a standard induction motor.

Fig. 14 is a detailed study of the phenomena which take place during the moment the machine synchronizes. This test was made under 150 per cent. load conditions and shows in a clearer manner than the previous oscillogram the gradual transformation of the secondary current into direct current and also shows the currents taken from the line during this period. It will be seen that there are no abnormal fluctuations in the line current.

Oscillogram Fig. 15 shows a similar condition for the same machine when starting idle and the resistance starter is short-circuited very quickly.

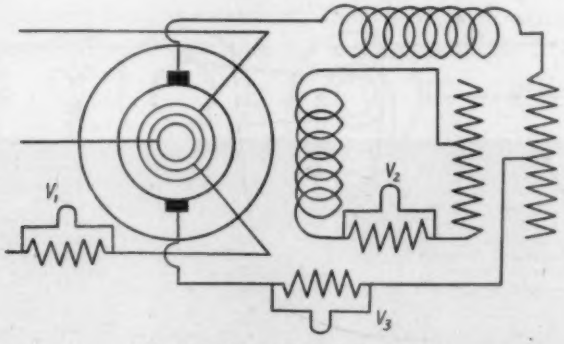
These last two figures are reproductions of tests made by the University of Washington in Seattle.

For the sake of completeness, in Fig. 16 is shown the connec-

FIG. 15*a*.

Current functions during the starting period with no load on the motor.
V_1 — Shows the current on the line.
V_2 — Shows the current in the a. c. field which becomes zero as soon as the motor pulls into step and operates as a synchronous motor.
V_3 — Shows the current in the d. c. field which does not become uniform unt.l the motor pulls into step.

FIG. 15*b*.

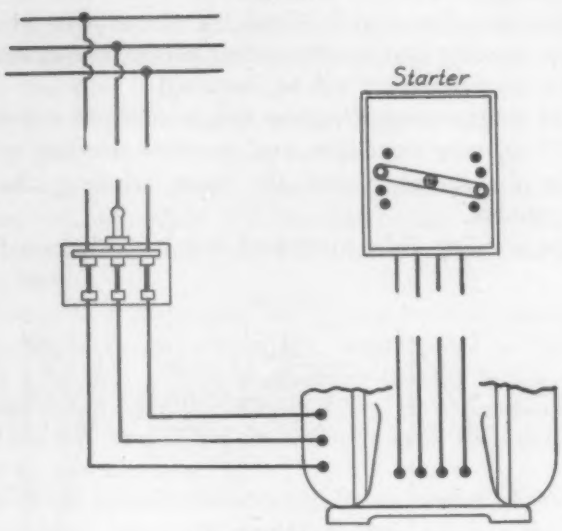


Starting Fynn-Weichsel motor.
V_1 = I load. V_2 = a. c. I field. V_2 (max.) = 18 amp. V_3 = d. c. I field. V_3 (max.) = 18 amp. V_1 (start) = 45. V_1 (run) = 3 amp. V_2 = 14 amp. (run).

tion between the starter and the motor. It will be noticed that this connection in every respect is identical to the connection of a slip-ring polyphase induction motor. The general appearance of these starters is also identical to that of a standard induction motor.

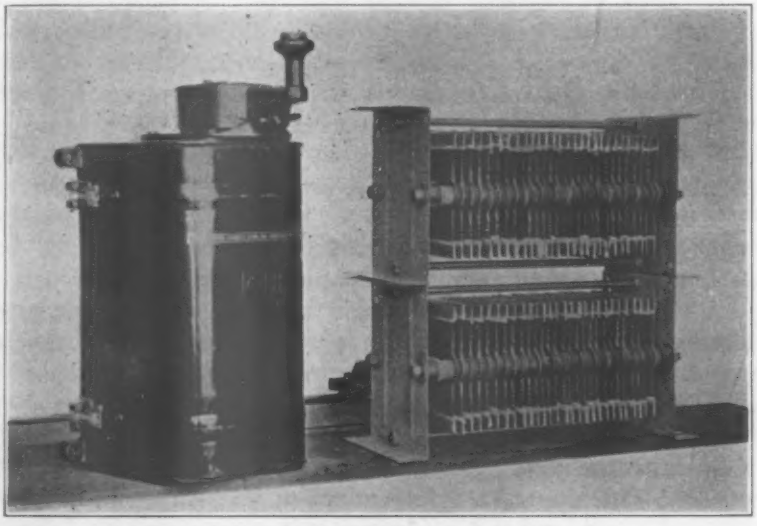
Fig. 17 shows the resistance units and the drum starter used in

FIG. 16.



Connection diagram.

FIG. 17.



Drum type starter used with Fynn-Weichsel motors above 50 hp.

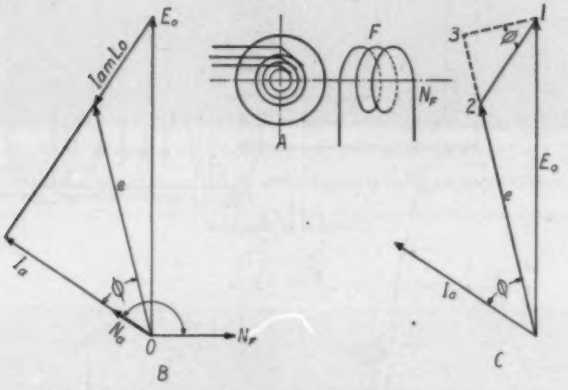
connection with the Fynn-Weichsel motors for capacities larger than 50 horsepower.

Having now discussed in detail the phenomena which occur during the starting and synchronizing period, the characteristics during the running period will be discussed.

Fig. 18 diagrammatically gives the condition in a synchronous motor with *separate* excitation, and its stator winding is assumed to be the d.c. member and the rotor winding the a.c. or primary member.

Let the winding F be so excited that it produces a field N_F.

FIG. 18.



Vector diagram for separately excited synchronous motor.

(See vector diagram, Fig. 18.) The armature rotating in this field produces an e.m.f. $O - E_o$, which, when machine operates as a motor, must be counterbalanced by a component of the impressed voltage e. Assume that the current drawn by the machine when operating as a motor is represented by the vector $o - I_a$. This current flows through the rotor winding and produces a field N_A. The rotation of the armature in this field produces a voltage $I_a m L_o$, which vectorially is 90 degrees displaced against the current vector $o - I_a$, as given in the diagram.

This expression, $I_a m L_o$, represents the self-induction voltage of the armature winding for the current I_a. (This should not be confused with the leakage self-induction voltage.) As the frequency $\times 2\pi = m$ and the self-induction L_o is constant, it follows that the vector $I_a m L_o$ is proportional at any time to the current I_a.

The total voltage necessary to counterbalance the e.m.f.'s acting in the machine is the impressed voltage e. For the assumed load conditions, the line current I_a has a phase displacement ϕ against the impressed voltage e. The energy taken by the motor is $I_a \times e \times \cos \phi$.

From this diagram, a new vector diagram can be derived by holding the impressed voltage, e, and the excitation, N_F, constant, *i.e.*, the voltage E_o constant. Therefore, the vector e in Fig. 18 is constant in magnitude and location, while the vector E_o is constant in magnitude but its end, No. 1, describes a circle around the zero point.

The line 1–2, representing for any load condition the voltage $I_a m L_o$, is, as previously explained, proportional to the current draw. If a vertical 1–3 is drawn from point 1 on the line 0–2, then it can be proven that the line 1–3 is proportional to the current $\times \cos \phi$. Therefore, the line 1–3 must be proportional to the input of the machine.

From this it follows that the maximum output of the machine will be obtained when the vector E_o has taken a position 90 degrees from the impressed voltage 0–2. The length of the vector E_o is a measure for the maximum output.

If it is possible to decrease the field produced by the armature for a given current, I_a, without changing the armature windings, then the self-induction voltage, $I_a m L_o$, decreases. That means, for a given vector length, 1–2, the corresponding current will increase inversely with the change in self-induction. For instance, if the self-induction is cut into one-half of its original value, then the same vector 1–2 is obtained with twice the current draw. In other words, the output of the machine is doubled.

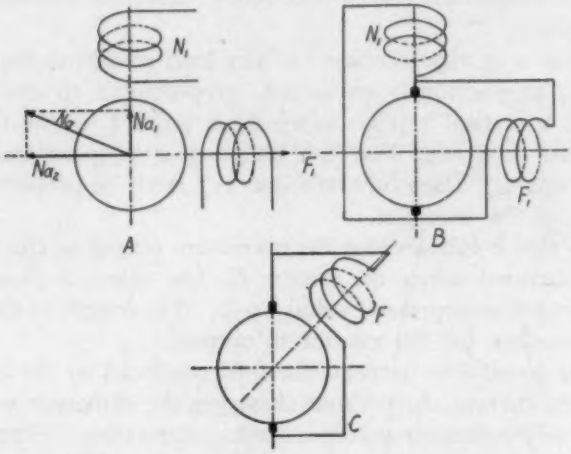
This condition can theoretically be obtained by placing on the stator a winding in such a position as to be coaxial with the armature reaction flux N_A. By exciting this winding, N, with a d.c. of such a direction as to produce a field opposed to the armature field, N_A, then the resultant armature field is decreased. For instance, if the ampere turns on the stator winding, N, are one-half of the armature ampere turns, then the resultant armature field is one-half of its original value for the same current draw.

The vector, N_A, *i.e.*, the armature field, can be imagined to be composed of the vector N_{A_1} and N_{A_2}. (Fig. 19.)

Instead of opposing, therefore, the total vector N_A by a wind-

ing which is in line with this vector, it is possible to oppose only the component vector N_{A_1}, which is at a right angle to the field winding F_1. By doing this the armature reaction is not completely neutralized as in the first case, but this arrangement has the advantage that the neutralizing armature winding N_1 can remain stationary in space, while in the first case the winding N_1 would have to be moved in space in accordance with the load on the machine.

FIG. 19.



By placing, therefore, winding N 90 degrees from winding F_1, it is possible to neutralize to a large extent the armature reaction and thereby increase the output of the machine. If it is desired to make the machine self-exciting, then the connection as given in Fig. 19 *B* can be used. It is a known fact that two windings, N and F_1, 90 degrees displaced from each other, can be replaced by one winding, as far as their magnetizing effect is concerned. This is represented by Fig. 19 *C*. In the design of the machine, the ratio of the windings N and F_1 is so selected that the angular displacement of the equivalent winding F against the brush axis is such as to give the relations which have been discussed under the subject of "starting and synchronizing." This combination is generally used in Fynn-Weichsel motors.

As in any other synchronous motor, the total flux in the machine which finally must counterbalance the impressed voltage

is practically constant in its magnitude, but its position in respect to the field winding depends on the load of the machine. Therefore, the direct current voltage appearing across the brushes of the commutator will to some extent vary with the load on the machine.

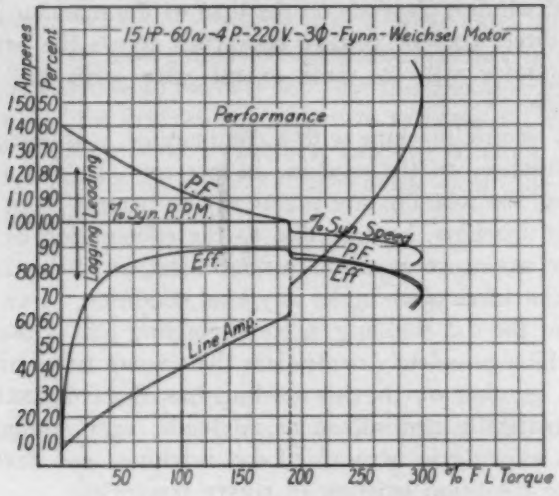
In any electric machine with a commutator, it is essential that the commutation on the machine be perfect. In this new type of machine, the relations are practically as perfect as in the best known d.c. machine, because due to the coöperation of the d.c. and the a.c. armature windings, a neutralization of the d.c. armature reaction takes place under any load condition. For any d.c. taken from the d.c. winding, a corresponding a.c. is taken from the line which completely neutralizes the ampere turns of the d.c. winding. In other words, this machine has its d.c. armature reaction automatically neutralized at all loads, very similar to the conditions existing in neutralized d.c. machines and nearly identical to the condition existing in rotary converters.

In addition to this automatic neutralizing effect, we have the favorable relations that in order to produce a certain d.c. voltage the number of turns on the armature can be kept relatively small because the velocity between the conductors and the field producing the d.c. e.m.f. is relatively high. This condition is contrary to that usually found in alternating-current commutator motors, which as a rule have their secondary member on the rotor and, therefore, the number of armature turns must be high. For a given number of commutator segments, this would mean a relatively large number of turns between segments, thus making the leakage self-induction of these individual turns very high.

Having now discussed the fundamental laws governing the theory of this machine, some actual tests on these motors will be of interest.

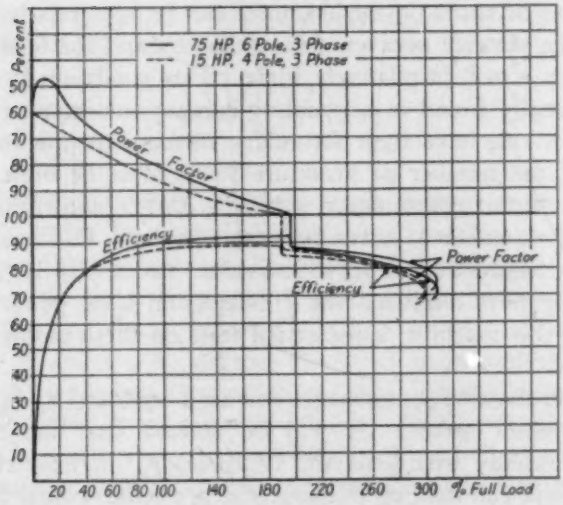
Fig. 20 shows a performance test on a standard 15-hp., 4-pole Fynn-Weichsel motor. It will be noticed that the efficiency increases rapidly with load and continues to increase even with loads beyond full load up to about 190 per cent. normal load. At about this point, the efficiency curve has a drop and from here on decreases gradually, similar to an induction motor efficiency curve. At the point where the efficiency curve changes abruptly, the motor transforms itself from a synchronous to an asynchro-

FIG. 20.



15-hp., 60 ~, 4-pole, 220 v., 3 φ Fynn-Weichsel motor.

FIG. 21.


75 HP, 6 Pole, 3 Phase
15 HP, 4 Pole, 3 Phase
Percent
Power Factor
Efficiency
Power Factor
Efficiency
20 40 60 80 100 140 180 220 260 300 % Full Load

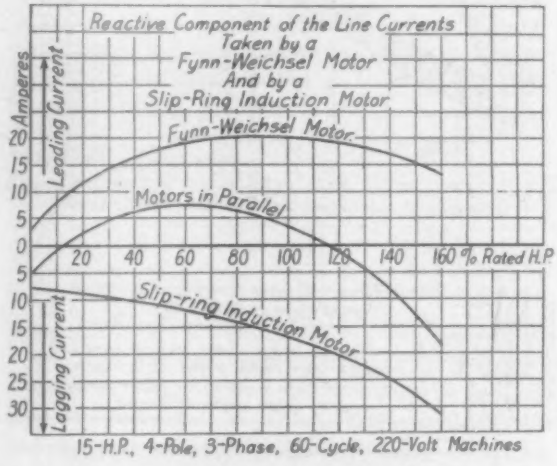
Comparison of power-factor and efficiency of Fynn-Weichsel motor.

nous motor. From 190 per cent. to 300 per cent. load, the machine operates as an asynchronous motor, while between the loads from zero to 190 per cent. the machine operates as a syn-

chronous motor. The power-factor of the machine is leading at no load and approaches unity with increasing load. In this particular case the machine has about 88 per cent. leading power-factor at full load and 60 per cent. leading power-factor at no load. Shortly before the motor ceases to operate as synchronous motor and continues to operate as asynchronous motor, the power-factor of the machine is approximately unity.

Fig. 21 depicts the performance of a 75-hp., 1200-r.p.m. Fynn-Weichsel motor compared with the performance of a 15-hp.,

FIG. 22.

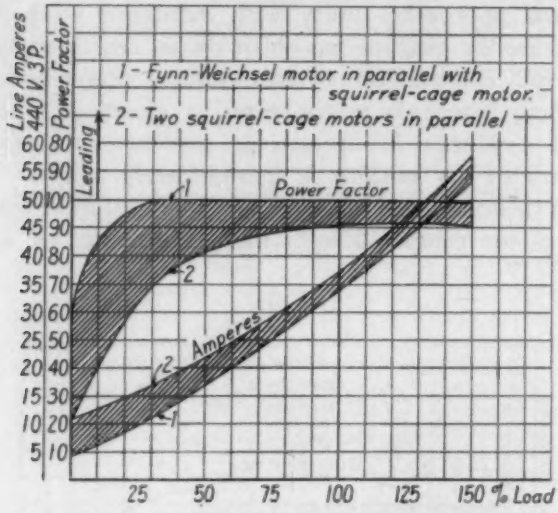


4-pole Fynn-Weichsel motor. It will be seen that in general these performance curves are similar, but that the efficiency for the larger unit is higher than for the smaller unit, a relation which is exactly the same as encountered in standard induction motors.

It was pointed out that usually the knowledge of the magnetizing current of a machine is more valuable than the knowledge of its power-factor. For this reason, a set of curves has been prepared which gives the negative magnetizing current taken by a 15-hp., 4-pole Fynn-Weichsel motor at the different load conditions. In this same diagram is also plotted the magnetizing current taken by a standard induction motor.

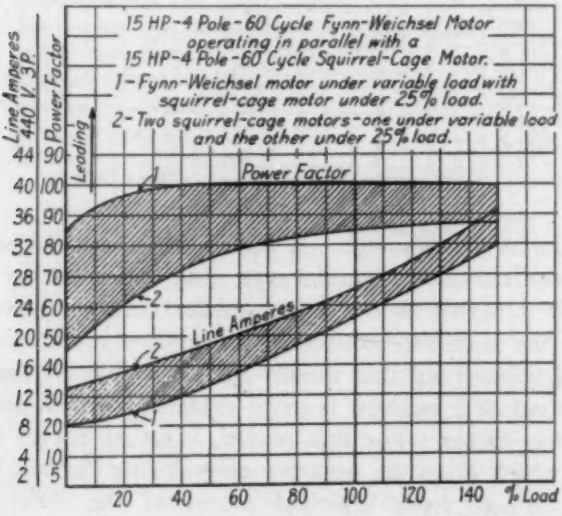
If both motors—the Fynn-Weichsel and the standard induc-

FIG. 23.


Line Amperes 440 V. 3P.
Power Factor
1 - Fynn-Weichsel motor in parallel with squirrel-cage motor.
2 - Two squirrel-cage motors in parallel
Leading
Power Factor
Amperes
25 50 75 100 125 150 % Load

15-hp., 4-pole, 60-cycle Fynn-Weichsel motor operating in parallel with a 15-hp., 4-pole, 60-cycle squirrel-cage motor, both machines equally loaded.

FIG. 24.


15 HP-4 Pole-60 Cycle Fynn-Weichsel Motor operating in parallel with a 15 HP-4 Pole-60 Cycle Squirrel-Cage Motor.
1 - Fynn-Weichsel motor under variable load with squirrel-cage motor under 25% load.
2 - Two squirrel-cage motors - one under variable load and the other under 25% load.
Line Amperes 440 V. 3P.
Power Factor
Leading
Power Factor
Line Amperes
20 40 60 80 100 120 140 % Load

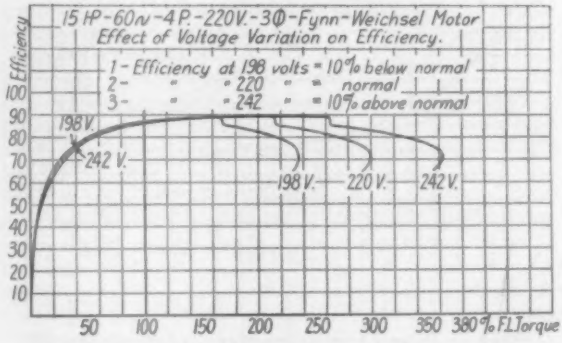
tion motor—are operated in parallel on the same line and are equally loaded, then the resultant magnetizing current taken from the line will be represented by the difference between the magne-

tizing current of the induction motor and that of the Fynn-Weichsel motor.

This is given in Fig. 22. This figure shows that a magnetizing current taken from the line for the combination of these two machines is very small over the whole load range. There exists a slightly negative magnetizing current under normal loads and a small lagging magnetizing current at fractional loads as well as at heavy overloads. From this it follows that the power-factor of the current furnished to these two motors must be very nearly unity. This is borne out by actual tests.

Fig. 23 shows the power-factor which occurs when two squirrel-cage motors are operating in parallel and are equally

FIG. 25.



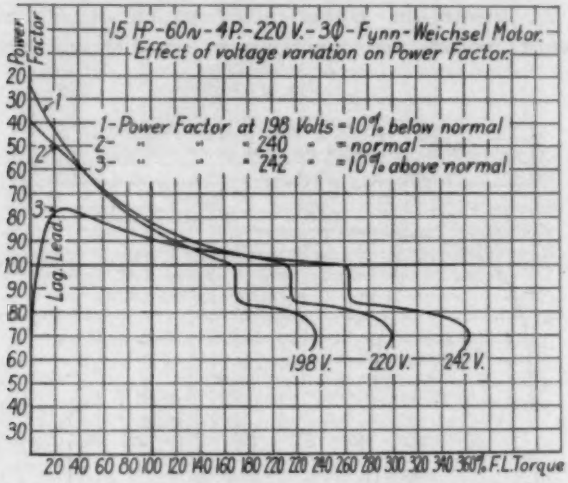
loaded. The curves Nos. 1 represent the condition when one of the machines is replaced by a Fynn-Weichsel motor.

The power-factor when a Fynn-Weichsel and squirrel-cage motor are operating in combination is nearly unity over the whole load range. Besides the advantage gained in power-factor, there is naturally a consequent gain in current draw from the line. This has been shown by the shaded area.

While in this case the Fynn-Weichsel and the squirrel-cage motor were operating under equal loads, a condition may arise in practice where one of the machines is loaded heavily while the other is loaded lightly. Assuming that the squirrel-cage motor operates with only 25 per cent., *i.e.*, under very poor power-factor, and the Fynn-Weichsel motor load is varied from zero to its maximum, then the current draw from the line and the power-factor under these conditions are given in Fig. 24.

The power-factor over the whole working range is nearly unity, and the gain in current draw is very appreciable when the Fynn-Weichsel motor is used in place of the squirrel-cage motor. Therefore, the general statement can be made that if a number of squirrel-cage motors are operating in parallel with a number of Fynn-Weichsel motors, and the ratio of these motors is properly selected, the power-factor on the system is kept at practically unity or any other desired value over nearly the whole load range

FIG. 26.


15 HP-60~-4P.-220 V.-3Ø-Fynn-Weichsel Motor.
Effect of voltage variation on Power Factor.
Power Factor
1-Power Factor at 198 Volts = 10% below normal
2- " " " 240 " = normal
3- " " " 242 " = 10% above normal
Lag
Lead
198 V.
220 V.
242 V.
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360% F.L. Torque

of the installation. Consequently an installation of this kind has a very materially decreased current draw from the line.

Not only the normal operating characteristics of a machine are of interest to the operating engineers, but also the characteristics under abnormal conditions are of great importance. The behavior of this motor under some of the most frequently encountered abnormal line and operating conditions is shown in the next figures.

Fig. 25 gives the efficiency of this motor for normal voltage and ± 10 per cent. variation; also, the influence of the voltage variation on the maximum torque of the machine. It will be noticed that the efficiency is very little influenced, while the maximum torque as synchronous as well as induction motor varies approximately with the square of the voltage. The effect of volt-

age variation follows, therefore, the same law which governs standard induction motors.

Fig. 26 shows the influence of the voltage variation on the

FIG. 27.

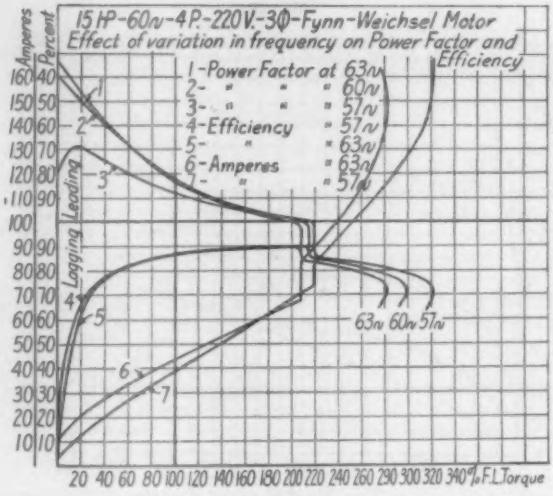
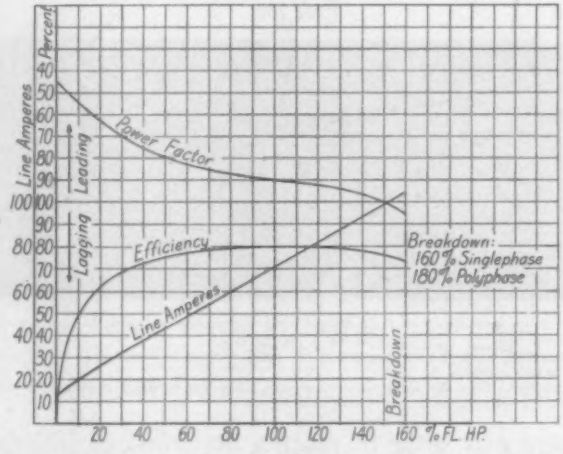

15 HP-60~-4P.-220V.-3Φ-Fynn-Weichsel Motor
Effect of variation in frequency on Power Factor and Efficiency
1-Power Factor at 63~
2- " " " 60~
3- " " " 57~
4-Efficiency " 57~
5- " " 63~
6-Amperes " 63~
7- " " 57~
Amperes
Percent
Lagging
Leading
63~ 60~ 57~
20 40 60 80 100 120 140 160 180 200 220 240 260 290 300 320 340 % F.L. Torque

FIG. 28.



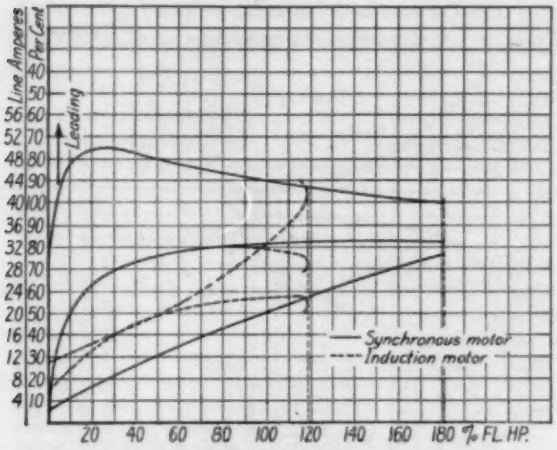
15-hp., 60-cycle, 4-pole, 3-phase Fynn-Weichsel motor operating on a single-phase line.

power-factor of the machine. Generally speaking, the power-factor approaches unity the higher the voltage. The influence of

frequency variation on the performance of the machine is given in Fig. 27. Generally speaking, decreased frequency has a similar effect on the characteristics as increased voltage.

Besides the abnormal line conditions which have just been dis-

FIG. 29.



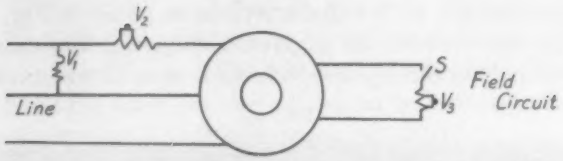
7½-hp., 60-cycle, 4-pole, 3-phase Fynn-Weichsel motor operating as synchronous motor and as induction motor with main field open.

FIG. 30a.

V_1—Result of opening the d. c. field circuit with the motor under full-rated load. V_1 is the line voltage on the motor. No disturbance is indicated.
V_2—Line amperage on the motor when the field circuit is opened at full load. Current oscillates to a small extent.
V_3—Direct current field showing point at which field was opened, giving exact place where motor went from synchronous to induction operation.

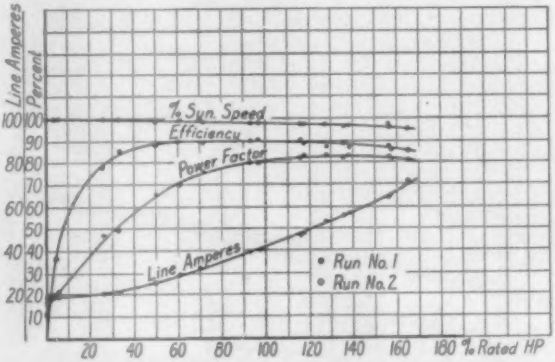
cussed, there may arise in practice abnormal conditions in the motor itself or in the wiring to the motor. For instance, one fuse in the three-line wires leading to the machine might blow and then the motor has to operate as single-phase machine.

FIG. 30*b*.



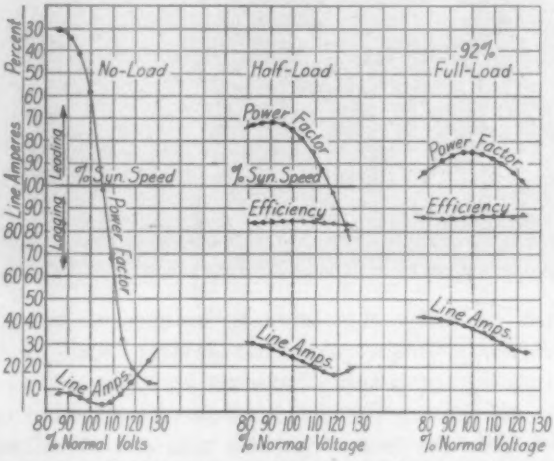
Opening field circuit, under load, on 15-hp. Fynn-Weichsel motor.
Synchronous motor imput = 16.6 hp. at 0.91 p. f. loading. V_1 = 60 ~ line voltage = 230 volts.
V_2 = line I = 30 amperes initial. V_3 = field current = 31.5 amperes.

FIG. 31.



Performance curves for Fynn-Weichsel motor. 15-hp., 4-pole, 3-phase, 60-cycle, 220 volts.
Operated at normal voltage as an induction motor.

FIG. 32.



Curves for Fynn-Weichsel motor. 15-hp., 4-pole, 3-phase, 60-cycle, 220 volts.
Operated at various voltages.

Under these conditions the machine changes into a single-phase synchronous motor with a characteristic as given in Fig. 28. The increase in line current for a given horsepower is similar to that found in standard three-phase induction motors when operated on

FIG. 33.

single-phase. Usually this increase in current safeguards the motor sufficiently if the protection devices, such as fuses and circuit breakers, are properly selected.

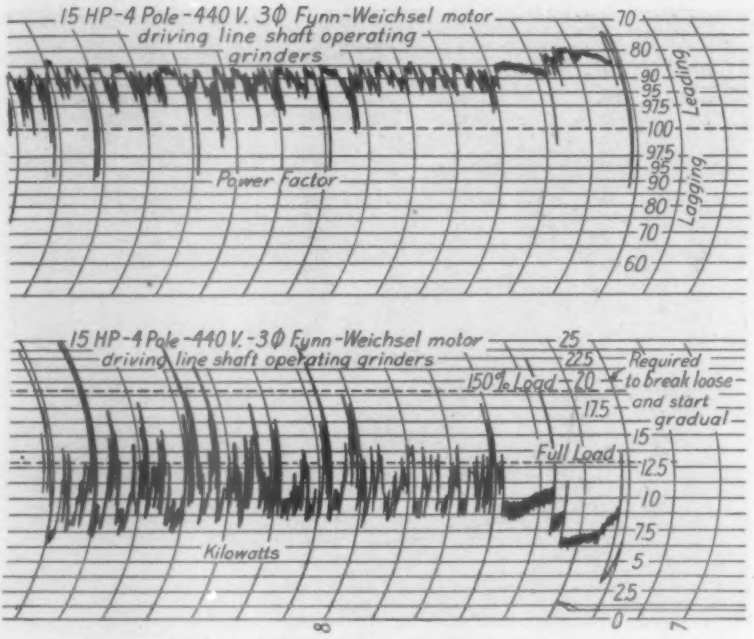
If, for any reason, the circuit of the d.c. exciting winding is interrupted, then the motor operates as a polyphase motor with a single-phase secondary. This results in a decreased output of

the machine and poor power-factor. The performance of the machine under these conditions is given in Fig. 29.

Fig. 30 shows the oscillogram of the line current of the motor under these conditions. The alternating-current pulsates in its magnitude in the same manner as occurs in any polyphase induction motor running with single-phase secondary.

If, for emergency reasons, the commutator winding is cut out and the stator windings are short-circuited, then the motor oper-

FIG. 34.



ates as a standard induction motor with performance as given in Fig. 31.

Fig. 26 shows that the power-factor approaches unity with increasing voltage. This is also shown in Fig. 32, where the power-factor as function of voltage is given for different load values. It shows that especially at fractional loads the power-factor changes quite rapidly with increasing voltage.

This characteristic is very fortunate, as it has a stabilizing effect on the line voltage. If, for instance, the line voltage tends to increase, then the correcting effect due to the Fynn-Weichsel

motor decreases and has a tendency to prevent the voltage from rising. On the other hand, if the voltage tends to decrease, then the correcting effect of the Fynn-Weichsel motor is a maximum and tends to increase the voltage.

The power-factor problem has, as stated above, been realized for years to be one of tremendous importance and due to lack of suitable power motors with good operating and starting characteristics, occasionally idle running over-excited synchronous motors

FIG. 35.

have been connected in parallel to the installation which demands a heavy magnetizing current. These idle running synchronous motors in this case operate for the sole purpose of producing a heavy negative magnetizing current which neutralizes the magnetizing current taken by the installation. Due to the fact that in this case the magnetizing current is first allowed to be created in its full magnitude and later is neutralized, it follows that the losses in such a system must be rather heavy.

A detailed calculation shows that an installation consisting of squirrel-cage and Fynn-Weichsel motors is more efficient than

the same installation consisting of induction motors only and the power-factor of the installation being corrected by additional apparatus installated for the purpose of producing leading or negative magnetizing current.

Although this new machine has been on the market only a relatively short time, a number of installations make use of the beneficial effect of this motor. Some typical installations are demonstrated in the following slides:

Fig. 33 shows a set of grinders driven by Fynn-Weichsel motors. This installation is particularly interesting, as grinding wheels produce heavy peak loads and whenever the load on the grinding wheel is very heavy the motor pulls out of step, operates as an induction motor, and as soon as the peak ceases, the machine returns to normal synchronous motor operation. Records of the power-factor and K.W. input to this machine are given in Fig. 34.

Fig. 35 shows an installation in a marble cutting and polishing factory. The peculiar characteristic in this industry is that the cutting and polishing must be done with absolutely constant speed in order to obtain a uniform polish. The synchronous speed of the Fynn-Weichsel motors driving the installation has, therefore, resulted in a materially improved product.

Another interesting feature in this installation is the large amount of inertia of the driven wheels. No difficulty has been encountered in starting and driving the motor up to synchronous speed, and the running operation has also proven to be perfect.

In closing it may be stated that up to the present no limit for the size of these machines is foreseen. Machines of 100-hp. capacity have been built and 200-hp. machines are in state of construction.

The Secular Distribution of Scientists. G. SARTON. (*Isis*, No. 19, Vol. vi (4), 1924.)—One of the consequences of the violation of the neutrality of Belgium by Germany was the suspension of the publication of this admirable periodical devoted to the history of science and civilization. It now appears again, and again it is printed in Belgium. Its editor is studying the distribution through the centuries of men of science and of significant anonymous works. He has come down to the close of the thirteenth century. "These 1248 scientists may be divided into four main groups according to the languages which they used: (1) Greek, Syriac, Armenian, etc., corresponding to the ancient Greek world and to Eastern Christendom,

362; (2) Latin and European vernaculars, corresponding to Western Christendom, 373; (3) Hebrew, Aramaic, Arabic, Persian, corresponding to Israel and Islam, 324; (4) Sanskrit, Tibetan, Chinese, and Japanese, corresponding to India, Central Asia and the Far East, 189.

"A curve presents the numbers of scientists in the East and West, respectively, from 900 B.C. to 1300 A.D. From the initial date to 600 B.C. the West was in the lead; thence to 650 A.D. the West became the more productive, but for the next 500 years the hegemony of science returned to the Eastern World. After 1150 A.D. the East increased only a little its output of scientific men, while the West showed vastly greater activity. A second diagram setting forth the distribution through the centuries, according to the four groups above mentioned, leads to this reflection." "Greek influence was paramount down to the sixth century; then, for one century, the Hindu and Chinese; and from the eighth to the eleventh century, and to an astonishing extent, the Muslim. This makes it clear why knowledge of Arabic is as essential for understanding mediæval thought as knowledge of Latin and Greek. Indeed, it is indispensable for a deeper study of the eighth to eleventh centuries. After the eleventh century, Western Christendom has been the main leader."

G. F. S.

Density of Mercury. SCHEEL and BLANKENSTEIN. (*Zeit. f. Physik,* Vol. 31, p. 202.)—After the discovery of isotopes it became desirable to investigate the density of that specimen of mercury which had been used in preparing the legal standard of electrical resistance. This was taken from a stock of unknown origin. Another specimen was likewise examined. The densities at 0° came out 13.59540 and 13.59558. The difference is greater than can be accounted for by errors of the experiment. Since one body of the mercury had been far more often distilled than the other, there may be a difference in the proportions of isotopes present.

G. F. S.

Some New Methods for the Measurement of Thermal Conductivity. T. BARRATT and R. M. WINTER. (*Phil. Mag.*, Feb., 1925.)—Let a rod of circular cross-section, of which the length and radius are given, be placed in an enclosure of constant temperature. To one end heat is supplied at a known rate. After equilibrium has been attained, the difference in temperature between the hot end and the enclosure is found, and also the excess of temperature of one point, at a known distance from the hot end, above the enclosure temperature. From these data alone a method is given for obtaining the value of the thermal conductivity. The formula involves hyperbolic functions.

The work of Despretz in the same field a long time ago is recalled to mind.

G. F. S.

A CONVENIENT METHOD FOR THE GENERATION OF HYDROGEN SULPHIDE GAS.*

BY

ABRAHAM HENWOOD, Sc.D., RAYMOND M. GAREY, B.S., WOOLF GOLDBERG, B.S., and ELMER FIELD, M.S.

Central High School, Philadelphia.

THE method that we wish to recommend to the attention of chemists has the following characteristics:

(*a*) The apparatus required is very simple and inexpensive, consisting merely of a 15-cm. test-tube fitted with singly bored cork and delivery tube.

(*b*) The volume of H_2S per unit volume of charge is exceedingly high. Ten c.c. of the charge yields about 2000 c.c. of H_2S gas.

(*c*) The gas is evolved in a copious stream upon the application of a bunsen burner flame not more than 1 inch high. This evolution continues at an undiminished rate till the charge is exhausted.

(*d*) The evolution of gas ceases within one minute after the flame is removed. This is a decided merit as it minimizes the danger of contaminating the air of the laboratory.

(*e*) After exhaustion of the charge, the residue, which consists of a dry friable mass, is readily removed from the tube, leaving it ready for a new charge.

(*f*) This residue is small in bulk and its disposal is free from all the inconveniences attending the disposal of the gritty residue and "spent acid" of the conventional iron sulphide-acid method.

(*g*) The H_2S is pure, free from hydrogen and spray of metallic salt solutions. These points facilitate absorption and render a wash bottle unnecessary.

The reaction utilized is that of sulphur on paraffin wax [1] at a temperature somewhat above that at which sulphur is in the plastic state. As stated above, the flame of a bunsen burner adjusted to a height of about 1 inch sets up the condition required for a copious evolution of the gas.

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* Communicated by Doctor Henwood.

[1] J. S. GALLETLEY: *Chem. News*, **24**, 162 (1871).

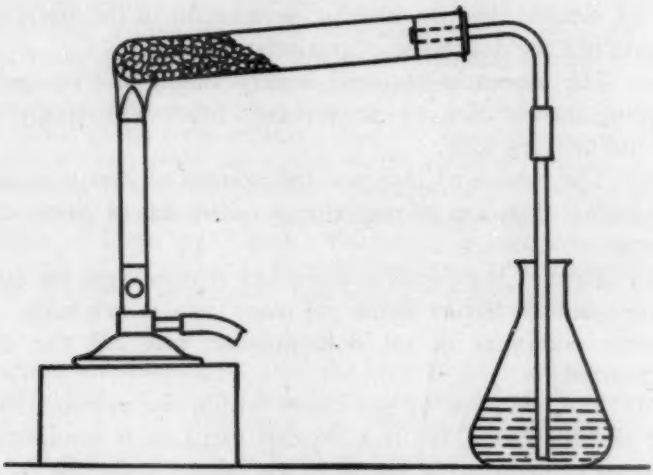
The action seems to be substantially as follows:

$$C_nH_{2n+2} + (n+1)S \longrightarrow (n+1)H_2S + nC$$

We have found it convenient to incorporate the reacting materials with finely divided ignited asbestos. This facilitates the removal of the spent charge and seems to minimize the danger of volatilizing paraffin and sulphur.

The apparatus is arranged as sketched in Fig. 1.

FIG. 1.



As the action proceeds the flame is shifted to positions progressively nearer the open end of the tube.

A charge of 5 grams, or about 5 c.c., gives sufficient H_2S to precipitate 3 grams of copper as CuS.

This method has been tried out with a class of about forty students in qualitative analysis with entirely satisfactory results.

We feel that the method will be welcomed in colleges and analytical laboratories.

On the Impact with Liquid Surfaces of Solid Bodies of Various Shapes. G. ERIC BELL. (*Phil. Mag.*, Feb., 1925.)—A series of interesting shadow photographs is given, showing cylinders with axes vertical entering water or turpentine with a velocity of about 250 cm. per sec. With water but little disturbance of the surface takes place, provided the cylinder is clean. If it is coated with oil, a basin-like cavity forms at the surface. A cylinder pointed at the lower end enters the liquid smoothly. In turpentine the disturbance produced is more marked than in water. G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

INVESTIGATIONS ON THE PLATINUM METALS.

VII. ARC SPECTRA OF THE PLATINUM METALS (4500 TO 9000 Å.).[1]

By W. F. Meggars.

[ABSTRACT.]

In other papers of this series mention has been made of the use of the spectrograph to follow the progress of chemical separation of the platinum metals. When materials approximating spectroscopic purity were prepared in this bureau an investigation of the arc spectra was undertaken primarily for the purpose of securing data in the red and adjacent infra-red regions where no data on the emission spectra of the platinum metals existed. Specially sensitized plates were employed to record the spectra with large diffraction gratings, and many hundreds of new lines were measured in the yellow, orange, red, and infra-red regions. Comparison with previous observations in the regions common to the old and to the new measurements showed that the former were incomplete. This led to an extension of the latter to shorter waves, thus including almost all of the visible spectrum, and made it possible to carry out a more extensive comparison of the spectroscopic purity of the materials used by the different observers. New values of wave-lengths and estimated relative intensities are given in six tables as follows: 1260 lines for ruthenium (4498.16 to 8867.84 Å.), 572 lines for rhodium (4503.80 to 8615.23 Å.), 172 lines for palladium (4497.66 to 9234.02 Å.), 942 lines for osmium (4500.74 to 8644.8 Å.), 605 lines for iridium (4500.97 to 8426.11 Å.) and 239 lines for platinum (4498.75 to 8762.48 Å.). The wave-lengths were measured relative to the secondary standards in the spectrum of the iron arc, and each value is, in general, the mean of from two to ten determinations. The probable error of these values rarely exceeds one one-hundredth of an Ångström unit. Six short tables giving lines ascribed to platinum metals by other observers, but not visible on the new spectrograms are subjoined to the major tables, and most of these lines are iden-

* Communicated by the Director.

[1] Scientific Papers, No. 499. Price, ten cents.

tified as impurities in the materials at the disposal of the earlier observers. Intercomparison of the results of the new measurements indicate that the metals used in this investigation were exceptionally pure, since even the most intense lines characteristic of each particular element rarely, if ever, appeared in the spectra of the other elements.

UNITED STATES GOVERNMENT MASTER SPECIFICATION FOR BLACK WATERPROOF DRAWING INK.[1]

THE United States Government master specification for black waterproof drawing ink was adopted by the Federal Specifications Board, on December 6, 1924, after it had been submitted to manufacturers and others for criticism.

The specification requires that the ink shall be an aqueous suspension of carbon black with the necessary ingredients added to prevent separation or settling out of the pigment and to prevent the growth of mold. The ink must flow freely from an ordinary drawing pen upon tracing cloth or paper. It must dry in ten minutes or less, so that the lines can be rubbed with the finger without smudging. The lines must be intensely black and opaque. Exposure to sunlight or to ultra-violet light must cause no fading (absence of dyes). Washing with water, gasoline, benzene, or carbon tetrachloride must cause no smudging or running of the ink. The ink must show no settling of pigment when allowed to stand undisturbed for two weeks. A sample inoculated with mold spores must show no growth of mold in two weeks.

UNITED STATES GOVERNMENT MASTER SPECIFICATION FOR INDELIBLE MARKING INK FOR FABRICS.[2]

THE United States Government master specification for indelible marking ink for fabrics was adopted by the Federal Specifications Board, on December 6, 1924, after it had been submitted to manufacturers and others for criticism.

Two types of ink are recognized: (*a*) For laundry and household use, and (*b*) for marking blankets and unsized or unstarched goods. These two types are necessary, because if articles are washed soon after marking, as in laundries, the ink must develop

[1] Circular No. 196. Price, five cents.
[2] Circular No. 197. Price, five cents.

its full color and fastness at once. Ink of this type might contain substances that would cause staining or other damage to goods that are bought in quantity, marked, and laid away on shelves until needed. For this, ink of type (*b*) should be used.

The specification gives no requirements as to the composition of the ink, but prescribes certain tests. Pieces of fabric are marked, and next day are washed in a solution of soap and soda, rinsed, dried, and again washed, etc., six times in all. They are similarly treated six times each with solutions of oxalic acid, sodium bisulphite, and chlorine. After all this the marks must still be legible. Other tests are made to find out whether the ink weakens the fabric or causes staining in a zone around the actual marks.

UNITED STATES GOVERNMENT MASTER SPECIFICATION FOR SOLE LEATHER.[4]

A UNITED STATES Government master specification promulgated by the Federal Specifications Board on November 5, 1924, for the use of the department and independent establishments of the Government in the purchase of sole leather (vegetable tanned) in the form of backs, bends, blocks, or cut soles.

The use of brined, green-salted, and dry-salted hides is permitted; to be tanned either with oak bark or a combination of vegetable tanning materials. The selection of the leather for backs and bends requires that they be free from holes, cuts, deep wrinkles, and surface blemishes excepting that 25 per cent. of the pieces may contain as many as eight open grub holes or three open grub holes and one small brand or hip mark not over 6 inches in the longest dimension. Blocks and cut soles are to be cut from such a selection of bends.

Under detail requirements it is specified that backs and bends shall gauge not less than 12/64 inch (nine iron) at a point on the back 18 inches from the root of the tail; that the leather shall not crack open on the grain when bent through an angle of 180° over a form 3 inches in diameter; that the leather shall not show piping when bent through an angle of 180° over a form 4 inches in diameter; that the water absorption shall not exceed 25 per cent.; and that the chemical constituents shall conform to the requirements of the following table:

[4] Circular No. 198. Price, five cents.

Chemical Constituents.

Moisture	14% maximum

Percentage on Moisture-free Basis.

	Minimum.	Maximum.
Water soluble	..	30
Hide substance	35	45
Grease (petroleum ether extract)	3	8
Acidity (modified P. & S. method)	..	1
Total ash	..	2
Portion of water soluble as glucose and salts	..	30
Portion of glucose and salts as Epsom salts	..	50
Degree of tannage	60	80

In sampling for test purposes the same method is used for backs and bends. For each bend unit sampled one piece is taken on the back beginning 15 inches from the root of the tail, one on the back beginning at a point 4 inches from the shoulder end and a third on the belly edge beginning at a point 30 inches from the butt end. Five backs or bends are to be sampled for each lot of 200 or fraction thereof and the samples for each lot treated separately. In the case of blocks and cut soles five are to be taken from each lot of 25 dozen.

Detailed methods of procedure for all the tests required are also included in the specification.

SIMPLIFIED PRACTICE RECOMMENDATION NO. 15, BLACKBOARD SLATE.[8]

IN AN effort to eliminate waste and to conserve a natural resource, the National Slate Association in conference with allied interests and under the auspices of the division of simplified practice of the United States Department of Commerce has drafted a simplified practice recommendation, which is No. 15 in the "Elimination of Waste" series of the department.

There has long been an obvious need of establishing some standard of conformity between the producers of blackboard slate and the ultimate consumers. It is clearly desirable that a limit be set for standard sizes and that the number of such sizes be reduced to the lowest limit consistent with current demand and conditions. At the same time the establishment of reasonable tolerances has been needed to prevent undue waste in quarried slate slabs, inci-

[8] Simplified Practice Recommendation No. 15.

dent to working a natural rock to exact dimensions. Furthermore, such tolerances are needed to expedite deliveries, and to make it unnecessary to await actual completion of finished wall spaces, before making up the required slate slabs.

Simplified Practice Recommendation No. 15 consummates the following reductions in sizes of blackboard slate:

	From	To
Fixed wall blackboard (slab heights)	90	3
Portable, or small blackboards (sizes)	141	14
School, score, memorandum slates (sizes)	20	8

corresponding to eliminations 96.6, 90 and 60 per cent., respectively.

It is believed that among the advantages to producers, distributors and users, and traceable to an adherence to this recommendation, will be:

(1) The quarry mills will be able to stock the sizes specified in anticipation of demand, thus avoiding the labor embarrassments attendant upon the occurrence of slack seasons.

(2) A natural resource will be conserved, for the mills will not have to sacrifice ends of slabs in making up exact space divisions.

(3) This recommendation will prove advantageous and convenient to architects, engineers, and others when specifying permanently framed or mounted slates for bulletins, score boards, shipping and train records, and other reportorial purposes.

(4) Specification of the recommended sizes will obviate the delay and expense usually attached to orders for specials.

(5) The widespread observance of these recommendations should bring many economies within the reach of producers, distributors, and users, which condition should play an important part in creating a greater demand for slate.

SIMPLIFICATION OF STRUCTURAL SLATE FOR PLUMBING AND SANITARY PURPOSES.*

FOLLOWING extended study of widespread diversity in specifications covering the use of structural slate for plumbing and sanitary purposes, a tentative elimination-of-waste program was

* Simplified Practice Recommendation No. 13. Price, five cents.

prepared by representative men in the slate industry, for the approval of all interests in attendance at the annual meeting of the National Slate Association, on January 21, 22 and 23, 1924, in New York, N. Y.

During the last day of this meeting, which was held under the auspices of the division of simplified practice, of the United States Department of Commerce, it was pointed out that a complete survey of the field had been made of the products listed by manufacturers throughout the country, and that all recorded sizes had been considered. Also, it was shown that an analysis of the sizes called for in the orders received by the various producers established the fact that the majority of orders for plumbing and sanitary slate are but slight variations from a comparatively few basic dimensions, and these basic dimensions were retained to serve as a foundation for the present program. Furthermore, in order that such a recommendation as this may not too closely restrict the applications and uses of slate, a survey has been made of other materials, such as soapstone, marble, concrete, enameled ironware, porcelain ware, etc.

Slate, being a natural product, can be cut to any desired sizes without the employment of special dies, patterns, molds, castings, etc., to meet any unusual conditions, but the recommended sizes are suggested for the purpose of encouraging a demand that will justify some production of units for stock. Such predetermined stocking will provide employment for quarry and mill workers during slack periods, and will expedite shipments on orders for the standard sizes.

Some of the sizes shown in this recommendation have already been adopted by several producers, in accordance with former studies and surveys, and they can, therefore, be economically supplied by all producers.

The specification and use of these recommended plumbing and sanitary slate sizes, by architects, contractors, engineers, plumbers, school boards, industrial plant owners, club and gymnasium directors, and others requiring slate for such purposes, will facilitate building operations.

Construction items which will be affected include: Laundry tubs; sink and tub combinations; sink and two-tub combinations; sinks with or without integral backs and with one or two drain-

boards; sink tops; slop hoppers; shower stalls; toilet inclosures, and urinals.

The new program will become effective on January 1, 1925. This program recommends a reduction in the number of varieties of dimensions, and has regard for adequate thicknesses. The immediate effect is an average reduction of 87 per cent. in sizes and dimensions of seven items of slate for plumbing purposes; and of 81 per cent. in three items of slate for sanitary purposes.

SIMPLIFIED PRACTICE RECOMMENDATION ON STEEL BARRELS AND DRUMS.[1]

THE unnecessarily great diversity of dimensions and capacities of steel barrels and drums has caused manufacturers and users of these products to cast about for a means of eliminating such sizes as are in slight demand, or for which another size can be readily substituted.

So long ago as November 5, 1922, a preliminary meeting of the manufacturers was held in Cleveland, Ohio, which authorized a survey to be made and requested the coöperation of the division of simplified practice of the Department of Commerce in calling a general conference of all interests affected at which there could be formulated a recommendation to be presented to the industry.

The general conference was held on March 26, 1924, at the Department of Commerce in Washington, D. C. Discussion was limited to containers with capacities of not less than ten gallons and there was prepared a list of such items as are to be considered standard stock. This list contains twenty-four varieties, a reduction from sixty-six, or of approximately 63 per cent. The conference recognized that there is one type for which there is still a considerable, though decreasing, demand. It recommended that this class be considered as an "obsolescent type"; it is considered as certain of elimination in the near future, but is in too large use at present to warrant immediate elimination.

With regard to thickness of material it was recommended that gauges of steel be used in the manufacture of barrels and drums of recognized capacities not less than the minimum as prescribed by rule 40 of the classification bureau of the Interstate Commerce Commission.

[1] Simplified Practice Recommendation No. 20. Price, five cents.

A standing committee of the industry was appointed and the effective date for the recommendation was fixed as January 1, 1925.

BRASS LAVATORY AND SINK TRAPS.[8]

EARLY in 1923 manufacturers of brass lavatory and sink traps began to regard the steadily increasing variety of sizes, styles and finishes of these commodities as an unnecessary burden on the industry, and, therefore, an avoidable economic waste. Several of the manufacturers met in Washington, D. C., on November 16, 1923, to review the situation and discuss the possibilities of coöperative action to reduce the prevailing diversity. This discussion developed the obvious advantages of such reduction and the meeting having decided that such action was both feasible and highly desirable, request was made to the division of simplified practice of the Department of Commerce for its coöperation in securing the active assistance of all interests in the formulation and application of this waste-eliminating plan.

At this preliminary meeting data were submitted by five producers showing that there was then being fabricated 1114 different combinations of brass lavatory and sink traps, of which 382 represented 98½ per cent. of the total sales. The remaining 732 combinations, therefore, were manufactured and carried in stock to satisfy only 1½ per cent. of the demand.

The general conference was held in Washington, D. C., on March 6, 1924, under the auspices of the division of simplified practice of the Department of Commerce. There resulted a unanimous recommendation that seventy-two items selected should be adopted as standard stock items. In addition, it was recommended that there be eliminated all gauges other than Nos. 17 and 20 B. & S., the furnishing of all brass lavatory and sink traps less connections, and the stamping of the name of the manufacturer and the gauge upon each.

January 1, 1925, was decided upon as the date on which the recommendations should become effective and the original simplification committee of the industry was appointed to continue its work of coöperation with the Department of Commerce and the various groups in the industry, looking to such future revisions as may later appear desirable.

[8] Simplified Practice Recommendation No. 21. Price, five cents.

SIMPLIFIED PRACTICE RECOMMENDATION NO. 24, HOSPITAL BEDS.[1]

THE movement for reduction in variety of lengths, widths, and heights of hospital beds was started early in 1923 through the interest shown in simplification by the executive secretary of the American Hospital Association. The successful reduction of household beds, mattresses, and springs from seventy-eight lengths and widths to one standard length and four standard widths naturally led to similar action regarding hospital bed sizes.

A careful survey was made under the direction of the committee on general furnishings and supplies of the American Hospital Association and the tabulated results showed that out of 92,167 beds reported there were in use thirty-three variations in length, thirty-four variations in width, and forty-four variations in height.

At the request of the association mentioned above, an invitation was sent out under date of May 19, 1924, to manufacturers, jobbers, hospital associations, and other users of hospital beds, to attend a general conference on June 3, 1924, at the Department of Commerce. An agenda was prepared in advance, based on the results of the survey and submitted to the conference for consideration. The conference unanimously approved the simplified practice recommendation for one standard length, one standard and two special widths, and one standard height.

For general hospital use, the length will be 78 inches between head and foot posts (inside); a width of 36 inches (of end angles of springs); and a height of 27 inches from floor to top of springs, inclusive of casters, etc. For certain institutional use, the need for a narrower bed is recognized, in which case the recommended width is 33 inches. For private room use, where a wider than standard bed is desired, the recommended width is 39 inches.

The conference further recommended that the new schedule go into effect January 1, 1925, subject to regular annual revision by a similar conference.

It is expected that widespread adoption and application of this recommendation will prove of much advantage in decreasing present variety in sizes; in simplifying manufacturing, and in facilitating distribution and purchase of this commodity.

[1] Simplified Practice Recommendation No. 24. Price, five cents.

The Heat Developed during Plastic Extension of Metals. W. S. FARREN and G. I. TAYLOR. (*Proc. Roy. Soc.*, A 743.)—"When a soft metal, such as annealed copper or aluminum, is deformed while cold, either by stretching, hammering, rolling, or other method of 'cold working,' it hardens; that is, the forces necessary to deform it increase as the amount of plastic deformation increases. The physical state of 'cold worked' metal is undoubtedly different from that of the metal in its original soft or annealed state, and various explanations have been put forward to account for the difference." Perhaps amorphous material develops at the planes where slipping has taken place during deformation. If, then, from the crystals amorphous material has formed, there has been a change of phase and the internal energy of the material has undergone a change. This investigation has for its purpose to find whether all the work done on the substance during deformation is converted into heat. If the heat be too small in quantity to account for all the work expended, then there should be a change of the internal energy of the metal. The author comments upon the little work that has been done in this line of investigation. He was able to find just one reference to such work, and that in the "Dictionary of Physics."

For the measurement of the heat developed the calorimeter for more than one reason had to be rejected. "The method adopted was to measure the rise in temperature which occurs during a rapid plastic extension of the bar. For this purpose a thermocouple was used and the temperature was recorded photographically on a moving plate." To have the thermocouple surrounded on all sides by material at the same temperature, it was placed inside of a hole bored from end to end of the metal to be stretched and the silver foil to which it was soldered was pressed against the metal. The lag of the apparatus for registering temperature was taken into account.

To get the work done in extending the metal an apparatus was devised by which a force of 2500 pounds could be applied in two seconds, while at the same time a clear stress-strain diagram was recorded. When steel with outside diameter of .31 inch was stretched 6 per cent. of its length, its temperature rose 3.41° C., which after correction becomes 3.69°. Had all the work done been effective in developing heat the rise of temperature would have been 4.20°. Thus only 88 per cent. of the work done went to produce heat. Copper gave a corresponding value of 92 per cent., aluminum of 93 per cent., and a single crystal of the last metal 95 per cent. "One remarkable feature of the table is the constancy of the ratio of the increase in internal energy to the work done on the specimens during different stages of the test. It is the same during the first extension when the metal is very soft and hardening rapidly as it is in the last extension when it is quite hard and only hardening slowly. It seems therefore that the increase in internal energy does not bear any very direct relationship to the hardening." G. F. S.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

NOTE ON THE RELATIONSHIP OF PHOTOGRAPHIC EMULSION FOG TO GRAIN SIZE.[1]

By A. P. H. Trivelli, E. P. Wightman and S. E. Sheppard.

A STUDY of " deterioration fog " which is found in emulsions kept for variable periods without exposure to light. Using definite conditions of development an experimental emulsion showed an initial fog density of 0.09 which increased in one month to 0.5. Measurements of developability of emulsions recoated in one-grain layers were made and the results correlated with the size, μ^2, of grains. The percentage of grains fogged seems to follow an equation similar to Silberstein's equation of the quantum theory of photographic exposure.

The Destruction of Berthelot's Bomb Calorimeter. C. MOREU. (*Comptes Rendus*, Feb. 25, 1925.)—During the war this famous piece of apparatus was used in the study of explosives. It was in such patriotic service that it came to its end December 16, 1918. " The explosion," says Professor Moreu, " took place in my laboratory and, by a fortunate combination of circumstances no person was injured, although a few minutes earlier I was holding the bomb in my hands. Originating from the studies of Berthelot and Vieille, it had been employed for more than thirty years by generations of thermochemists in the measurements of heats of combustion and at the moment of its disappearance it was still an incomparable working instrument in spite of the glorious memories attached to its long past."

When the question of replacement came up financial difficulties presented themselves. The laboratories of France are so badly off that a public collection was needed for them a year ago. In addition the platinum used in the lining, no less than 1300 g., that at the time of Marcelin Berthelot was worth somewhat less than gold, had attained a value much in advance of it. Nonetheless platinum must be used to secure freedom from attack during the reactions to be carried out. The bomb was accordingly redesigned, not by theory and the results of experience alone, but by successive experiments. The thick platinum lining was replaced by a triple layer of platinum,

* Communicated by the Director.

[1] Communication No. 214 from the Research Laboratories of the Eastman Kodak Company, and published in *Phot. J.*, **65**, 134, 1925.

gold and copper. A different way of closing the orifice was employed with the final result that not 1300 g. but 128 g. of platinum were used. After 100 heats of combustion have been determined by it, the instrument has shown itself a worthy successor to its scientific ancestor.

G. F. S.

Special Weather Service for Amundsen's Flight. (U. S. Department of Agriculture Clip Sheet No. 356, April 20, 1925.)—A special service of weather forecasts for the benefit of Captain Amundsen's projected aeroplane flight this spring from Spitsbergen to the pole and return has been arranged by Norwegian meteorologists in coöperation with the Weather Bureau of the United States Department of Agriculture. The Norwegian forecasters are to issue their bulletins by radio from the ship of the expedition, stationed at Spitsbergen. The Weather Bureau will send out twice-daily cipher reports of meteorological observations at a selected list of stations in Alaska, Canada, Bermuda, and the United States. Through the coöperation of the Navy Department these reports will be issued by radio from the Annapolis station (NSS) immediately after the broadcasting of the time signals at noon and 10 P.M., 75th meridian time. Each word of the meteorological report, in cipher, will be sent twice in order to increase the probability of effective transmission. In case the receiving apparatus of the expedition at Spitsbergen is not able to receive the Annapolis broadcast directly, the promoters of the expedition probably will make arrangements to have the reports relayed from some European radio station.

The broadcasting of weather reports from Annapolis will begin April 15th and will continue until May 31st, or until such time as the polar trip is completed.

Thermal Diffusion Measurements. T. L. IBBS. (*Proc. Roy. Soc.*, A 743.)—When a mixture of two gases is contained in a vessel one part of which is higher in temperature than another part, the lighter molecules tend to move toward the hot surface and the heavier molecules seek the cold area. In this paper careful experiments are described which measure the extent of the separation of the two gases by this process of thermal diffusion. For all mixtures used, except nitrogen-carbon dioxide, the permanent condition of separation was attained in three minutes. For the exception mentioned fifteen minutes were required. For a mixture of composition 32.7 per cent. H_2 and 67.3 per cent. N_2 "the difference in percentage composition by volume between the gas on the hot and cold sides" amounted to 3.67 per cent. with the cold side 11° C. and the hot side at 274° C. For the mixture of N–CO_2, in which the ratio of the molecular weights is only 3.14:1, a smaller degree of separation results. "For all mixtures the total separation is found to be nearly proportional to log T_1/T_2," where T_1 is the absolute temperature of the hot side and T_2 that of the cold side. G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

CITRUS PECTIN.[1]

By H. D. Poore.

[ABSTRACT.]

AN investigation was undertaken to determine the properties of citrus pectin and to devise a method for its production on a commercial scale. Results of previous work in this field are given, together with a very comprehensive bibliography.

The simple method used for making apple pectin can not be used for making citrus pectin. The best method of extracting citrus pectin was found to be to heat the finely ground peel or residue with acidified water and clarify the expressed extract with kieselguhr. The bitter principle was removed with alcohol from powdered pectin prepared from concentrated solutions of pectin in the laboratory and in a commercial plant. A process whereby the pectin extracts are concentrated to a paste and washed by a continuous system with a minimum quantity of denatured alcohol was devised. Little hope is indicated of distinguishing chemically between lemon, orange, and apple pectins; the composition, when calculated to the alcohol-precipitate basis, is much the same for each product. A standard jelly test for determining the quality of the pectins produced throughout the investigation was developed. The proportions of citric acid, sugar, and citrus pectin required to give good jellies were determined. The lower limit in the finished jelly for citric acid was 0.045 per cent.; for pectin, 0.20 per cent., and for sucrose, 37 per cent.

PRELIMINARY NOTES ON THE DIRECT DETERMINATION OF MOISTURE.[2]

By G. L. Bidwell and W. F. Sterling.

[ABSTRACT.]

MOISTURE is usually determined by drying to constant weight and considering the loss in weight as water. It is obvious that erroneous results are obtained in many instances. Substances

* Communicated by the Chief of the Bureau.

[1] Issued as *U. S. Dept. Agr. Bul. 1323*, March 9, 1925.

[2] Published in *Ind. Eng. Chem.*, **17** (Feb., 1925) : 147.

other than water may be liberated by heat, the sample may be partially decomposed or oxidized during heating, and humidity may affect the results. Preliminary trials at direct determination of moisture as actual water offer sufficient encouragement to warrant further study to determine the range of usefulness of the principle involved. A modification of an apparatus devised by Dean and Stock is used. Results indicate that by use of the modification the method may be extended to a wide variety of products. The sample is distilled with toluene. The drops of water are trapped in a calibrated tube as the excess toluene is returned to the sample. The foregoing disadvantages of the drying method are almost entirely eliminated.

VAPOR PRESSURES AND BOILING POINTS OF MONO- AND DIMETHYLANILINES AND MONO- AND DIETHYLANILINES.[3]

By O. A. Nelson and H. Wales.

[ABSTRACT.]

THE vapor pressures and boiling points of mono- and dimethylanilines and mono- and diethylanilines have been redetermined by the method devised by Smith and Menzies. The boiling points found for the mono- and dimethyl- and mono- and diethylanilines were 195.70°, 193.50°, 204.72° and 216.27°, respectively, at 760 mm.

OBSERVATIONS ON THE DRYING OF FLOUR.[4]

WITH NOTES ON ITS HYGROSCOPIC PROPERTIES.

By E. R. Smith and L. C. Mitchell.

[ABSTRACT.]

FLOUR dried *in vacuo* in loosely covered dishes gives uniformly higher percentages of loss in weight (moisture) than when it is dried in open dishes or at atmospheric pressure in either covered or open dishes.

Drying at atmospheric pressure in covered dishes gives erratic results because the covers retard evaporation.

[3] Published in *J. Am. Chem. Soc.*, 47 (March, 1924) : 872.

[4] Published in *Ind. Eng. Chem.*, 17 (Feb., 1925) : 180.

The water-oven method, with open dishes, gives variations in both duplicate and check duplicate determinations, which indicates that this method is both inaccurate and unreliable.

The property of flour of losing or gaining weight when exposed to the atmosphere of the laboratory shows that special precautions must be taken to prevent any change in weight when weighing the sample for analysis, during the period of cooling after it is dried, and when making the final weighing.

The ordinary desiccator, with anhydrous calcium chloride as the dehydrating agent, is of little value, if any, in preventing dried exposed flour from increasing in weight during the period of cooling.

EXTRACTION AND ESTIMATION OF LIPOIDS IN CEREAL PRODUCTS.[5]

By Olaf S. Rask and Isaac K. Phelps.

[ABSTRACT.]

THE official method for the determination of fats in uncooked cereal products extracts less than one-half of the lipoids or ether-soluble material in macaroni, as measured by the quantity extracted by the ammoniacal method described in this paper. In the case of egg noodles, the official method extracts about three-fourths of the quantity of lipoids extracted by the ammoniacal alcohol method. The lipoid content of egg noodles determined directly by the ammoniacal alcohol method checks with their lipoid content as computed from the lipoid content of their component materials, also determined by the ammoniacal alcohol method.

If ether-soluble material is combined with other materials, whether carbohydrate or otherwise, so as not to be extractable by ether, as believed by Nelson and Taylor in the case of starch, this combination can be broken by an ammoniacal alcohol solution without hydrolyzing the starch, so that apparently all ether-soluble material can be extracted by ether in uncooked flour products.

The Radium-emanation Content of Sea Air from Observations Aboard the Carnegie, 1915–1921. S. J. MAUCHLY. (*Terrestrial Mag.*, Dec., 1924.)—Determination of the radio-active content of the air was a regular feature of the work of the *Carnegie* during

[5] Published in *Ind. Eng. Chem.*, 17 (Feb., 1925) : 187.

all of the six voyages made by this non-magnetic yacht in connection with the magnetic survey of the earth undertaken by the Carnegie Institution under the direction of L. A. Bauer. Upon the first three voyages only relative values were obtained, but these were sufficient to show that the air over the sea contains much less radio-active material than is found over the land. "Further, it was evident from the shape of the decay curves that radio-active deposits obtained over the great oceans consist almost entire of the decomposition products of radium emanation." From 333 absolute measurements made on the Seven Seas it has been found that the radium-emanation content of sea air is 1.2×10^{-18} curies per cm.^{3}. This quantity would be at least doubled were there included in its determination bodies of air near land masses. Unusually high values were got in Behring Sea, off New Zealand, near the coast of Argentine, and off the French West African Coast. In all these four regions the prevailing winds blew from the land. "There remain ocean areas totalling at least half the surface of the earth over which the radium-emanation content is of the order of only 1 per cent. of that found over land." This small amount is quite inadequate to produce the ionization of the air over these remote water areas.

Bongard has suggested that at least part of the radio-active content of the lower air is due to the sun in some way. The great disparity between results obtained with air over water and with air over land negatives this theory, for an influx of radio-active matter from extra-terrestrial space would, no doubt, influence alike all the atmosphere whether over land or sea. G. F. S.

Lines of Equal Annual Change of the Magnetic Elements in 1915 for Latin America. H. W. FISK. (*Terrestrial Mag.*, Dec., 1924.)—Around the mouth of the Amazon the annual change in the declination amounted in 1915 to 14 minutes and the north end of the needle turned more and more to the west with the passage of time. There is a line coming down from South Carolina, through Cuba, and traversing the northwestern part of South America, along which there was no change of declination. In Mexico the annual change amounted to 4 minutes to the east.

There is an elliptical line in western Peru, Equador and Colombia along which the north end of the dipping needle moved downward at the rate of 14 minutes annually. Elsewhere in South America the change was less marked. In the West Indies the horizontal component of the earth's field was increasing most rapidly, while in the Amazon valley no change was taking place. "Prior to 1917 the value of the horizontal intensity was increasing generally throughout the central countries of South America, but recent observations indicate that this area of increase has greatly diminished, if it has not entirely disappeared." When the long-sought theory of the earth's magnetism is attained, the group of facts stated above will have an explanation. G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 15, 1925.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 15, 1925.

DR. WM. C. L. EGLIN, President, *in the Chair.*

Additions to membership since last report, 2.

The Chairman announced that the first business of the meeting would be the presentation of the Elliott Cresson Medal, and recognized Mr. Benjamin Franklin, who introduced Mr. Francis Hodgkinson, of Swarthmore, Penna., to whom had been awarded this medal for his work on turbo-electric appliances. The Chairman presented the medal and accompanying documents to Mr. Hodgkinson, who thanked the Institute for the honor conferred upon him.

Doctor Hoadley was then recognized and introduced Mr. Thomas M. Chance, of Philadelphia, who was awarded the Edward Longstreth Medal for his method and apparatus for the separation of materials of different specific gravities. The Chairman presented the medal and accompanying documents to Mr. Chance, who expressed his appreciation of the award.

Dr. Harry N. Holmes, Chairman of the Committee on Chemistry of Colloids, National Research Council, then presented the paper of the evening on "Silica Gels." The speaker described the evolution of the process of the preparation of silicic acid and its application for selective adsorption from mixtures of vapors or gases. He referred to the method of Patrick for drying silicic acid and his special heat treatment for the preparation of a gel, and gave an account of his own investigations in this field and the more porous silica gel which he has recently been able to prepare with some of his assistants. It was pointed out that the use of these various forms of silica gel must include solvent recovery, drying of air for the blast furnace, and for the vacuum ice process, recovery of sulphur dioxide and oxides of nitrogen, removal of offensive odors from air, removal of sulphur compounds from petroleum fractions, decolorizing certain liquids, recovery of gasoline from natural gas and many other uses. The subject was illustrated by experiments and diagrams.

After a brief discussion the thanks of the meeting were conveyed to the speaker. Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERSHIP NOTES.

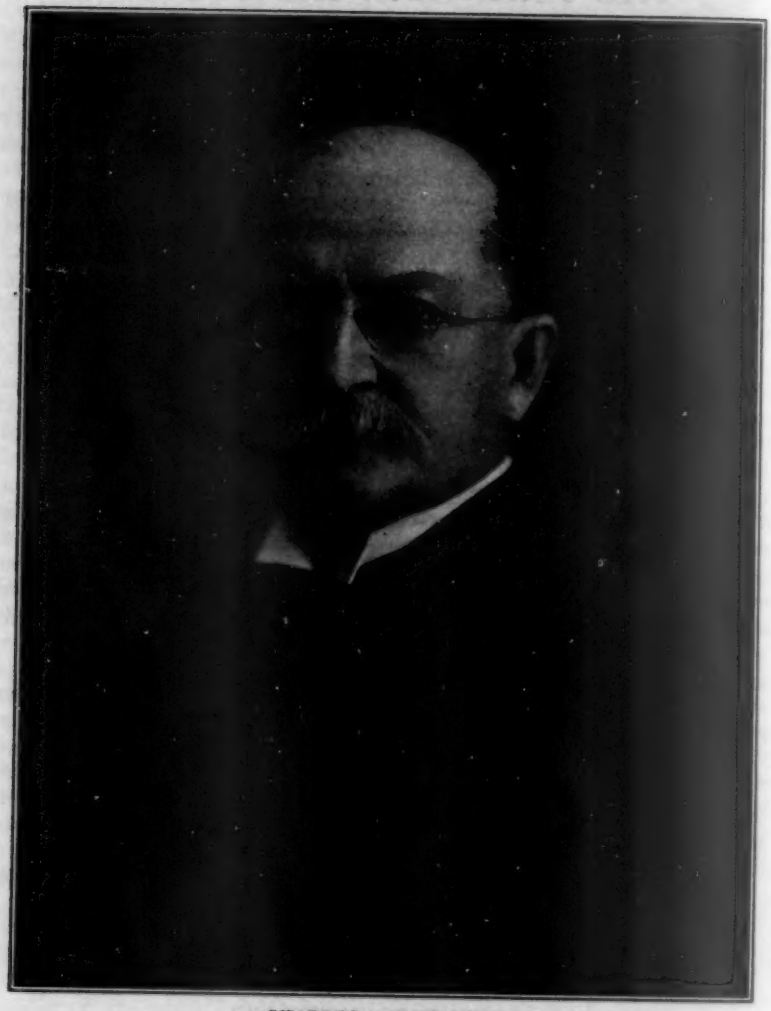
ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 8, 1925.)

NON-RESIDENT MEMBERS.

MR. ANDREW B. CRICHTON, Mining Engineer, U. S. Bank Building, Johnstown, Penna.

DR. GERALD L. WENDT, Chemist, Educator, State College, Penna.



CHARLES A. HEXAMER
Member, Board of Managers, 1904–1925.

RESOLUTIONS ADOPTED BY THE BOARD OF MANAGERS AT ITS STATED MEETING HELD WEDNESDAY, MARCH 11, 1925, IN REFERENCE TO THE DEATH OF MR. CHARLES A. HEXAMER.

Whereas: In the death of Charles A. Hexamer the Board of Managers of The Franklin Institute has lost a member who, for many years, has rendered a valued service, and

Whereas: Each member of the Board is sensible of a feeling of personal loss in his unexpected death, therefore be it

Resolved: That the Board of Managers of The Franklin Institute records with deep regret the death on March 9, 1925, of Charles A. Hexamer, who for the past forty-five years has been an active member of The Franklin Institute and for the past twenty-one years a member of its Board of Managers, and be it

Further Resolved: That the sympathy of the Board be extended to Mrs. Hexamer and family in their great bereavement, and that a copy of the foregoing preambles and resolutions be sent to Mrs. Hexamer and also published in the JOURNAL.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of the Stated Meeting held Wednesday, April 1, 1925.)

HALL OF THE INSTITUTE,

PHILADELPHIA, April 1, 1925.

MR. HAROLD CALVERT *in the Chair.*

The following reports were presented for final action:

No. 2818: Separating Materials of Different Specific Gravities.

The specific subject considered in this investigation is the Sand Flotation Process as applied to the washing of coal and its separation from slate and bony coal.

In order to secure a liquid having a specific gravity greater than that of coal and less than that of slate, a machine was devised in which a mixture of sand and water is continuously agitated, the proper rate of agitation giving liquid of the required specific gravity. In pouring a mixture of coal and slate into this machine the coal rises to the top, where it is separated for distribution and the slate sinks to the bottom, from which it is removed.

This machine is having an extensive use in the Pennsylvania coal mines and is considered by the Sub-committee of Investigation an important help in the separation of coal from non-combustible materials.

This device is not only applied to the separation of freshly mined coal, but also to the reclamation of coal from the refuse of culm banks.

The report ends as follows:

> "In consideration of the superiority of this method over other methods, its novelty and its successful operation, not only in the separation of coal from bone and slate, but also in the reclamation of coal, The Franklin Institute awards its Edward Longstreth Medal to Thomas M. Chance, Esq., of Philadelphia, Penna., for his Method and Apparatus for Separating Materials of Different Specific Gravities."

No. 2828: The Work of Mr. Francis Hodgkinson in the Improvement and Development of the Parsons Type of Steam Turbine.

Mr. Hodgkinson's interest in this work began in 1885 when he was associated with the firm of C. A. Parsons and Company, during the early development of steam turbines. Mr. Hodgkinson has spent practically his entire life in the development of this work and has been personally responsible for much of the improvement that has resulted in the larger types of the Parsons' turbine.

The report ends as follows:

"In consideration of his successful pioneer work in the introduction of the steam turbine as a prime mover, his fundamental contributions to its development in both theoretical and practical fields and his many inventions that have aided in its ultimate successful application, The Franklin Institute awards its Elliott Cresson Medal to Francis Hodgkinson, of Swarthmore, Penna."

The following report was presented for first reading:

No. 2835: Plastometer.

GEORGE A. HOADLEY,
Acting Secretary.

LIBRARY NOTES.

PURCHASES.

American Society for Testing Materials.—Proceedings of the Twenty-seventh Annual Meeting, 1924. Vol. 24. One volume in two parts. 1924.

AUERBACH, FELIX.—Die Methoden der theoretischen Physik. 1925.

BALY, E. C. C.—Spectroscopy. Vol. 1, edition 3. 1924.

BLANCHARD, H. F., and OLIVER, A. F.—Electrical Equipment of the Automobile. 1924.

Chemical Society of London.—Annual Report of the Progress of Chemistry for 1924. Vol. 21. 1925.

DEMELIUS, A.—Die Zuckerwaren: Einschliesslich der Fabrikation der Schokoladen und Lebkuchen der Neuzeit. Edition 3 by P. Born. 1922.

DRYSDALE, C. V., and JOLLEY, A. C.—Electrical Measuring Instruments. Two volumes. 1924.

FARNHAM, D. T., HALL, J. A., KING, R. W., and HOWE, H. E.—Profitable Science in Industry. 1925.

FEITLER, SIEGMUND.—Die Zuckerfabrikation. 1913.

FRUWIRTH, C.—Handbuch der landwirtschaftlichen Pflanzenzüchtung. Vierter Band: Die Züchtung der vier Hauptgetreidearten und der Zuckerrübe. Edition 4. 1923.

GEBHARDT, G. F.—Steam Power Plant Engineering. Edition 6. 1925.

GREINER, W.—Verdampfen und Verkochen unter besonderer Berücksichtigung der Zuckerfabrikation. Edition 2. 1920.

GUNTHER, R. T.—Early Science in Oxford. Vol. 2. 1923.

HALDANE, J. B. S.—Callinicus: A Defence of Chemical Warfare. 1925.

HEUSER, EMIL.—Text-book of Cellulose Chemistry. Translated from the second German edition by C. J. West and G. J. Esselen, Jr. 1924.

Kaiserliche Normal-Eichungskommission.—Tafel zur Ermittelung des Zuckergehalts von Zuckerlösungen. 1911.

Livre du Cinquantenaire de la Société Française de Physique. 1925.

McKAY, R. F.—The Principles of Machine Design. 1924.

Minerva Jahrbuch der gelehrten Welt. Twenty-seventh Jahrgang. 1925.

MULLIKAN, S. P.—A Method for the Identification of Pure Organic Compounds. Vol. 4. 1922.

NEUMANN, P.—Zucker und Zuckerwaren. 1920.

RECTOR, T. M.—Scientific Preservation of Food. 1925.

THOMAS, WILLIAM.—Complex Salts. 1924.

THOMPSON, M. DEK.—Theoretical and Applied Electrochemistry. Revised edition. 1925.

VAN KLOOSTER, H. S.—Lecture and Laboratory Experiments in Physical Chemistry. Edition 2. 1925.

WATSON, WILLIAM.—Advanced Textile Design. Edition 2. 1925.

WILLIAMS, HAL.—Mechanical Refrigeration. New and enlarged edition. 1924.

ZELLER, T.—Der Kampf zwischen Rohr- und Rübenzucker. 1920.

BOOK REVIEWS.

THE ROMANCE OF FORGOTTEN TOWNS. By John T. Faris. xiv–335 pages, numerous illustrations, 8vo. New York, Harper and Brothers, 1924. Price, $6.

"I've stood upon Achilles' tomb
And heard Troy doubted. Time will doubt of Rome."

Troy is no longer doubtful, the excavations, begun by Schliemann, having not only disclosed its ruins, but those of a number of other cities that rose upon its site. From England comes the news that London Bridge and St. Paul's are falling down, but Macaulay's New Zealander has not yet taken his stand on a broken arch of the one to sketch the ruins of the other.

Mr. Faris has selected a popular subject, and one that will attract attention over a wide area of the United States. Within the past quarter of a century a very active interest in local history has been aroused, and many localities have become "shrines to no code or creed confined." Tradition has had a large share in making the stories, and it is unfortunate that, in many cases, correct history has been submerged in a mass of invention and misrepresentation. Art has contributed a considerable share to originating and perpetuating error in this respect. West's picture of Penn's Treaty, Trumbull's picture of the signing of the Declaration and Leutze's picture of Washington crossing the Delaware are far from representing the original scenes.

Mr. Faris' book, however, is not of a misleading type. It deals with ascertained facts, derived from written records. Some of the incidents are, indeed, within the memory of persons living. Wisely, the book has been made to cover a wide area, and will, therefore, be interesting to persons scattered over the whole country. Obviously, a drastic selection had to be made. Even a record of all the incidents of rise, fall and extinction of settlements in one of the larger and older states would require an encyclopædia, while a full account of such incidents in the entire country would extend the work to the dimensions of Guicciardini's "History of Italy," which Macaulay regarded

as the acme of prolixity. Any large city will furnish in itself the material for a good-sized volume but the interest will be local. Philadelphia, for instance, restricted by its founder to limits of about two square miles, was expanded by the Consolidation Act of 1854 to embrace the entire county of considerably over one hundred square miles, and the subsequent increase of population slowly but steadily captured local settlements and left them mainly memories. Such, however, is the influence of tradition and the attachment to local areas that the outlying districts may continue to bear their original names, at least unofficially, long after they have ceased to have any political or social value.

Turning over the pages of the book, one finds justification for the author's claim that whatever else some may regard as faults, lack of variety is not one. Many types of enterprises are detailed that have led to the establishment of towns that have had an important and often feverish existence and are not now on the map. All the stories are given in the clear and attractive style for which the author is well known. The topics range from the story of the establishment of the Pemaquid Colony in Maine in the first decade of the seventeenth century to the building of Pithole in Pennsylvania under the influence of the oil discovery in 1865. The range sweeps from Maine to Florida, from the Atlantic to the Pacific. Obviously it would be easy for the reviewer to protest the selection. Local interests will be both favorable and unfavorable, the former because a reader finds something mentioned about which he has knowledge, the latter because something else which he regards equally important is omitted.

History is being studied at the present day in a different manner than in earlier years. Economic influences have been recognized as powerful determinants. Carl Marx's materialistic conception of general history has been slow in making its way to general recognition, and, like the doctrine of evolution, has been denounced as subversive of morals and ethics, but the share that economic struggles have had in the world's history and especially in determining wars, is now a fundamental part of historical philosophy. The "Romance of Forgotten Towns" does not, however, deal with the philosophy of their history. As in "Marmion," which was a

> "tale of Flodden field,
> And not a history,"

Mr. Faris has given us a delightful narrative of human effort, honorable and commendable, but failing in permanent result. This is the fate of human enterprise taken as a whole. "Many are called but few are chosen." Yet, while this book does not make a point of the economic influence, that influence may be read in many of the chapters. On a larger scale than the incidents enumerated, may be noted the story of the competition between New York and Philadelphia. The latter, dominant through colonial times, became eclipsed by the former when the Erie Canal enabled it to secure the traffic between the lakes and the sea. George Washington, as a result of journey through the Mohawk Valley, in the period between his army service and the Presidency, foresaw this result, greatly to his disappointment, as he had hoped that the Potomac region would afford the best route from the country west of the mountains to tidewater.

The large number of excellent illustrations add to the value and usefulness of this interesting book.

HENRY LEFFMANN.

PROFITABLE SCIENCE IN INDUSTRY. By Dwight T. Farnham, James A. Hall, R. W. King and H. E. Howe. x–291 pages, illustrations, small 8vo. New York, The Macmillan Company. Price, $3.50.

This work, in the preparation of which four well-known scientists have collaborated, is intended to set forth in everyday language the value of pure science in the industries, a service especially needed in this country. The United States enjoys a high and well-deserved reputation in the field of mechanical invention, especially of labor-saving machinery, but in applied chemical science, no striking record has been made. The telegraph, telephone, high-power printing press, typewriter and type-setting machines, and the several forms of agricultural machinery testify to the ability, originality and practical spirit of American inventors. Perhaps we ought also to include the vacuum cleaner and cash register. Other nations have surpassed us in the development of important chemical industries. The triumph of Germany in the coal-tar industries is now so well known that it is tiresome to hear it quoted. There are other lackings, however, such as the contact process for sulphuric acid and the production of ammonia by nitrogen fixation.

Of late years, much has been done to awaken in the minds of the American public at large a sense of the value and importance of pure science, and to show that through such studies processes will be developed which are not only profitable but essential. The object of science is, indeed, the discovery of truth, and, in the last analysis, it is not a matter of moment to the investigator whether the data that will be determined will be of use or not, but the interesting fact is that in many cases discoveries apparently remote from practical application may become the initiative of most valuable results. The romantic story of helium is a case in point.

There is, fortunately, nowadays, in this country, a recognition by many persons, and especially by those in the great industries, that a close alliance of science with practice is essential to the greatest success in operation of plants. In the preface to the book in hand, a striking contrast is noted between the present industrial conditions and those prevailing during the last half of the last century, and especially about the time of the Civil War. Labor was abundant, cheap and earnest; incompletely developed transportation methods restricted competition and errors in manufacturing were less likely to be protested, as local conditions governed markets. Cheap raw materials likewise made careful supervision of waste less important. This is now much changed. Labor organization has introduced serious difficulties in many fields. It will be sufficient to note the enormously increased cost in the building trades, which has reacted most seriously upon the housing problem. The great advance in transportation methods, especially in overseas service, has widened the competitive conditions.

In view of these facts an active propaganda for a greater share of science in industry has been inaugurated in this country, and the volume in hand is an excellent contribution to the plan. Three mechanical engineers and a chemist contribute the text and have given us a book expressly suited to the business man and general reader. It is not intended as a work on technology, but as a presentation of facts to show how essential scientific supervision is to the proper conduct of industry. It is to be hoped that it will find a wide circle

of persons who will read, mark and inwardly digest its statements. It is illustrated with seventeen full-page plates covering a wide range of subjects. Numerous instances are related showing the pecuniary advantages that have followed the introduction of scientific methods into industries that have been unregardful in such lines. One of the most striking of these is the manner in which a trained man succeeded in saving large amounts of pulp which had been flowing into the sewers with the waste waters of the factory by the simple introduction of strainers. HENRY LEFFMANN.

MOLYBDENUM, CERIUM AND RELATED ALLOY STEELS. By H. W. Gillett and E. L. Mack. American Chemical Society Monograph Series. 299 pages, 68 illustrations, 8vo. New York, The Chemical Catalog Company, 1925. Price, $4.

The metallurgy of iron in several commercial forms goes back to a remote period, and the accumulated information is immense. The most ancient literature refers to the metal, and archeologists distinguish an "iron age" as one of the later stages in the evolution of civilization. There is a reference in the Odyssey to the hardening of steel by quenching the hot metal in water, and Lycurgus' "iron money" is a conspicuous incident in Greek financial history. Until comparatively recently, the production of steel was of such a nature that it could only be used for special purposes. The introduction of the Bessemer process brought the cost of manufacture of good quality steel within suitable bounds, and it at once began to replace wrought iron for many purposes. Steel rails constituted an early application of the product. The widening application of the alloy was aided by the introduction of processes by which inferior ores, such as those containing notable amounts of phosphorus, could be used.

An interesting feature of modern chemical industry has been the fact that what were long considered rare elements, the compounds of which were only seen as precious specimens in mineralogic collections or in cabinets of chemical preparations, have become fairly familiar, and even in some cases in excess of the demand. Cerium, vanadium, thorium, molybdenum, selenium and even thallium have ceased to be really rare, at least as to their compounds. The free metals have also been in some instances cheapened enormously. Fifty years ago, aluminum was selling at about $5 per ounce and was, of course, only seen as a specimen in the cabinet. Such metals as calcium, barium and thallium were only curiosities. Much change has come over the methods of steel manufacture in the last half century. Not only have the methods of making the older forms and standard steels been cheapened, but chemical and metallographic analyses have led to extensive knowledge of conditions that determine serviceability, and these results have prompted extensive research and the production of alloys of steel with different metals. Here the increase in the supply of metals formerly rare has been of material aid. To-day, industries have available steels and also iron alloys adapted to many purposes. One of the most useful is the iron silicide group, which has given to the chemical industries a material highly resistant to the common corrosives.

The work in hand is an extensive and thorough presentation of a research to determine the properties and applications of certain less familiar steels. The authors were respectively chief and assistant chemists in the U. S. Bureau

of Mines. In pursuing their research they have been aided by the authorities of that bureau and also by many private companies to which due credit has been given. The tests have included all the methods of determining the applicability of the various alloys, and the work is a valuable contribution to the metallurgy of the metal that has become such a prominent feature of modern industry. A special importance of molybdenum steel lies in the fact that the alloying metal can be obtained in large quantity within the borders of this country, while the bulk of the other specific alloying metals, nickel, manganese and chorium, are of foreign origin. The United States has the largest potential supply of molybdenum yet known, the deposit in Colorado being sufficient to yield 100,000 tons of the metal, sufficing for about 20,000,000 tons of steel. Some other large domestic deposits are known. The conclusion reached in the investigations recorded in the book is that molybdenum steel is a valuable and useful product. Cerium, however, has not given satisfaction so far, but the data are rather scanty, and besides, the compounds of cerium, although now much more abundant than in former years, due largely to the extensive use of monazite in the preparation of gas mantles, are yet in comparatively limited supply.

The book shows the usual excellence in make-up of the publishing firm and constitutes another gratifying evidence of the development of an independent industrial method in this country.

HENRY LEFFMANN.

LECTURE AND LABORATORY EXPERIMENTS IN PHYSICAL CHEMISTRY. By Henry S. van Klooster, Ph.D., Assistant Professor of Chemistry at the Rensselaer Polytechnic Institute, Troy, N. Y. Second edition, revised and enlarged. x–274 pages, numerous illustrations, 12mo. Easton, The Chemical Publishing Company, 1925. Price, $3.

The first edition of this book was reviewed in this JOURNAL in 1919 (vol. 188, p. 424). The present edition sustains the merits which were noted in that review and the author has taken the opportunity to revise the text and to make considerable addition.

The following paragraphs from the preface of the second edition will furnish a satisfactory statement as to the nature of the book and the improvements that have been made in the text:

"The chapters on catalysis, electrochemistry and ionic theory, solubility, colloid chemistry and adsorption, have been enlarged—and two new chapters dealing with radio-activity and miscellaneous experiments added. About one hundred new experiments have been described.

"Although originally planned only for classes in physical chemistry which, as a rule, do not comprise more than forty to fifty students, quite a number of elementary experiments useful to lecturers in general chemistry have been included. In giving these demonstrations before large audiences, it may be advisable to perform them on a larger scale than outlined in the text. This may be safely left to the individual lecturer and a change of the text on this account has not been made.

"Considering that a large number of the experiments described in the text are also well adapted to be performed by the student in the laboratory, the title has been modified so as to indicate this possibility."

HENRY LEFFMANN.

EINSTEIN'S THEORY OF RELATIVITY. By Max Born, Professor of Theoretical Physics in the University of Göttingen. Translated by Henry L. Brose, M.A. 293 pages, illustrations, 8vo. New York, E. P. Dutton and Company, no date. Price, $5.

Two English expeditions went to observe the solar eclipse of May 29, 1919, for the sole purpose of testing Einstein's prediction that light passing by the edge of the sun and therefore in a strong gravitational field was deflected from its path towards the sun. Not only was this observed, but the amount of the deflection agreed with the predicted value. Since then the work of Einstein and his so-called Theory of Relativity have been much in the public eye. Many books for the non-mathematician and the non-physicist have been written. Most of these are of little scientific value and they usually demonstrate more or less satisfactorily that all motion is relative, a fact known to scientists from earliest times. This book, however, is different and is one of the best, if not the best, popular exposition of Einstein's theories.

The first three chapters contain an admirable presentation of classical mechanics as founded by Newton. These are followed by two chapters on the fundamental laws of optics and electromagnetism as developed by Faraday, Maxwell, Lorentz and Hertz. Then comes a chapter on Einstein's special principle and this is followed by the final chapter on the general theory of relativity.

The mathematical sections of this book are easier to follow than the physical deductions made from them. The book is worthy of the attention of intelligent people with little mathematical knowledge. JAMES BARNES.

CALLINICUS. A Defence of Chemical Warfare. By J. B. S. Haldane, Cambridge University. 84 pages, 18mo. New York, E. P. Dutton and Company. Price, $1.

Callinicus, the encyclopædia tells us, is credited with being the author of Greek fire, a means of offence that was practised at an early period. The composition of the material he used is not known, but a well-known compilation of mixtures for incendiary purposes is the "Book of Fires" by Marcus the Greek. The full title of the Latin translation means "Book of Fires to Burn Enemies." Berthelot has furnished an excellent account of this work. The book under review is a defence of the recently invented methods which found so much application in the late war. Poisonous gas is, of course, the most striking feature, and much discussion has been carried on as to whether its use comes within the bounds of what leading statesmen and military authorities are aiming to establish, namely, that the methods of warfare should be directed rather to disabling the soldier temporarily than to killing him. It appears from carefully collected statistics that the mortality from "gassing" is much lower than from shell-fire. Indeed, there is some indication that some of these gases may be used therapeutically. In Doctor Haldane's book the *pro* and *con* of the case for chemical warfare are set forth clearly and concisely. It must be admitted, however, that no matter what may be the opinion of the public at large, chemical warfare in all its forms has come to stay.

HENRY LEFFMANN.

LE LIVRE DU CINQUANTENAIRE DE LA SOCIÉTÉ FRANÇAISE DE PHYSIQUE. 160 pages, numerous illustrations, 8vo. Paris, Revue d'Optique Théorique et Instrumentale, 1925. Price, in paper, 17 francs.

The Physical Society of France was founded after the War of 1870. Like the Mathematical Society, founded about the same time, the number of members is not limited by the constitution or by-laws. Anyone may become a member by paying the initiation fee and dues fixed by the rules, but every candidate has to find a couple of vouchers who will recommend him. It is to this free condition of membership that the prosperity of the society and its wide influence are largely due.

The association which filled a somewhat similar purpose prior to 1870, known as the Philomatic Society of Paris, was limited in membership.

The present volume contains speeches at a banquet celebrating the fiftieth anniversary and a collection of papers by prominent scientists contributed in recognition of the event. The actual date of the celebration was the 12th of December, 1923, the delay being probably due to the disorganizing influences of the war. The responses to the invitations to attend the affair were quite numerous. Representatives from France, England, Belgium, Italy and the Scandinavian countries are among those enumerated. The scientific papers are, as might be expected, of a high class and cover several phases of the developments in modern physics.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 205, The Effect of Changes in Compression Radio upon Engine Performance. By Stanwood W. Sparrow. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1925. Price, ten cents.

This report is based upon engine tests made at the Bureau of Standards during 1920, 1921, 1922, and 1923, and has been prepared for publication by the National Advisory Committee for Aeronautics. The majority of these tests were of aviation engines and were made in the altitude laboratory. For a small portion of the work a single-cylinder experimental engine was used. This, however, was operated only at sea-level pressures.

The report shows that an increase in brake horsepower and a decrease in the pounds of fuel used per brake horsepower hour usually results from an increase in compression ratio. This holds true at least up to the highest ratio investigated, 14 to 1, provided there is no serious pre-ignition or detonation at any ratio. To avoid pre-ignition and detonation when employing high-compression ratios, it is often necessary to use some fuel other than gasoline. It has been found that the consumption of some of these fuels in pounds per brake horsepower hour is so much greater than the consumption of gasoline that it offsets the decrease derived from the use of the high compression ratio. The changes in indicated thermal efficiency with changes in compression ratio are in close agreement with what would be anticipated from a consideration of the air-cycle efficiencies at the various ratios. Insofar as these tests are concerned there is no evidence that a change in compression ratio produces an appreciable, consistent change in friction horsepower, volumetric efficiency, or in the range of fuel-air ratios over which the engine can operate. The ratio between the heat loss to the jacket water and the heat converted into brake

horsepower or indicated horsepower decreases with increase in compression ratio.

Report No. 211, Water Model Tests for Semi-rigid Airships. By L. B. Tuckerman. 14 pages, quarto. Washington, Government Printing Office, 1925. Price, five cents.

The design of complicated structures often presents mathematical problems of extreme difficulty which are frequently insoluble. In many cases, however, the solution can be obtained by tests on suitable models. These model tests are becoming so important a part of the design of new engineering structures that their theory has become a necessary part of an engineer's knowledge.

For balloons and airships water models are used. These are models about 1/30 the size of the actual ship hung upside down and filled with water under pressure. The theory shows that the stresses in such a model are the same as in the actual ship.

In the design of the Army semi-rigid airship RS-1 no satisfactory way was found to calculate the stresses in the keel due to the changing shape of the bag. For this purpose a water model with a flexible keel was built and tested. This paper gives the theory of the design, construction and testing of such a water model.

Report No. 213, A Résumé of the Advances in Theoretical Aeronautics Made by Max M. Munk. By Joseph S. Ames. 46 pages, illustrations, quarto. Washington, Government Printing Office, 1925. Price, fifteen cents.

In order to apply profitably the mathematical methods of hydrodynamics to aeronautical problems, it is necessary to make certain simplifications in the physical conditions of the latter. To begin with, it is allowable in many problems, as Prandtl has so successfully shown, to treat the air as having constant density and as free of viscosity. But this is not sufficient. It is also necessary to specify certain shapes for the solid bodies whose motion through the air is discussed, shapes suggested by the actual solids—airships or airfoil—it is true, but so chosen that they lead to solvable problems.

In a valuable paper presented by Doctor Munk before the Delft Conference in April, 1924, these necessary simplifying assumptions are discussed in detail. It is the purpose of the present paper to present in as simple a manner as possible some of the interesting results obtained by Doctor Munk's methods.

PUBLICATIONS RECEIVED.

Molybdenum, Cerium and Related Alloy Steels, by H. W. Gillett and E. L. Mack. American Chemical Society Monograph Series. 295 pages, illustrations, 8vo. New York, Chemical Catalog Company, Inc., 1925. Price, $4.

Électricité Atmosphérique, by B. Chauveau, 2e fascicule, Le Champ Électrique de l'Atmosphère. 264 pages, figures, plates, 8vo. Paris, Gaston Doin, 1925.

Recent Progress in Engineering Construction, by C. M. Linley. 340 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1925. Price, $10.

The Modern Soap and Detergent Industry, by Geoffrey Martin. Volume II, The Manufacture of Special Soaps and Detergent Compositions. v.p.,

illustrations, quarto. London, Crosby Lockwood and Son, 1925. Price, 36 shillings.

Allen's Commercial Organic Analysis, fifth edition, edited by Samuel S. Sadtler and Elbert C. Lathrop. Volume III, Hydrocarbons, etc. ix–732 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1925.

Subject Index to Periodicals, 1921, issued by The Library Association. Section K, Science and Technology. 251 pages, quarto. London, The Library Association, 1924. Price, 1 pound 1 shilling.

National Advisory Committee for Aeronautics: Ninth Annual Report, 1923, including Technical Reports Nos. 159 to 185. 487 pages, illustrations, quarto. Washington, Committee, 1924.

Théorie Nouvelle de la Probabilité des Causes, by Stanislaus Millot. 35 pages, 8vo. Paris, Gauthier-Villars et Cie., 1925. Price, 5 francs.

Illinois State Water Survey: Bulletin No. 20, Comparison of Chemical and Bacteriological Examinations Made on the Illinois River during a Season of Low and a Season of High Water—1923–1924, by R. E. Greenfield, and A Preliminary Notice of the Sources of Pollution of the Streams of Illinois, by G. A. Weinhold, and R. E. Greenfield, with A. M. Buswell. 59 pages, maps and diagrams, 8vo. Urbana, no date.

American Telephone and Telegraph Company: Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1924. 41 pages, diagrams, 8vo. New York, Company, 1925.

Ontario Department of Mines: Thirty-third Annual Report, being Volume xxxiii, Part iv, 1924. Geology of the Upper Part of the English River Valley, and Geology of the Basin of Red Lake, District of Patricia, by E. L. Bruce. 48 pages, illustrations, maps, 8vo. Toronto, 1924.

National Advisory Committee for Aeronautics: Technical Notes, No. 216, The Velocity Distribution Caused by an Airplane at the Points of a Vertical Plane Containing the Span, by Max M. Munk. 8 pages, quarto. No. 217, Note on the Air Forces Caused by Pitching, by Max M. Munk. 6 pages, quarto. Washington, Committee, 1925.

United States Department of Commerce: Elimination of Waste: Simplified Practice Recommendation, No. 13. Structural Slates (for Plumbing and Sanitary Purposes). 14 pages, illustrations, 8vo. No. 15, Blackboard Slate. 7 pages, 8vo. No. 24, Hospital Beds. 7 pages, 8vo. Washington, Bureau of Standards, 1925.

United States Department of Commerce: Circular of the Bureau of Standards, No. 200, United States Government Master Specification for Heavy Rust-preventive Compound. 4 pages, quarto. Washington, Bureau of Standards, 1925.

Illuminating Engineering Bureau of the Westinghouse Companies: Bulletin E-105, Lighting the Home. 39 pages, illustrations, 8vo. New York, Westinghouse Lamp Company, 1925. Price, twenty-five cents.

An Apparently Anomalous Centrifugal Experiment. M. v. SCHWARZ. (*Physik. Zeit.*, Feb. 15, 1925.)—A glass cylinder, 10 cm. in diameter and twice as high, has in it about 250 g. of a heavy oil of specific gravity more than one. Upon this rests 8 or 10 cm.

of water. Both liquids are rotated in the same direction faster and faster by means of a rod. The water climbs up toward the top of the cylinder, so that its mass has a hollow space in the middle. On the other hand, the oil leaves the periphery of the cylinder and heaps up on the axis. With proper relations of viscosity and density the boss of oil may even rise up through the water. The configuration assumed by the two liquids is due to the greater friction of the oil against the glass which keeps the heavier liquid from attaining a speed of rotation as great as that of the water. G. F. S.

The Equality of the Velocities with Which α-rays Leave Polonium. IRENE CURIE. (*Comptes Rendus,* March 16, 1925.)—Geiger has verified to one part in 200 the equality of the initial velocities of α-rays from radium C. Miss Curie discovered differences in the lengths of the paths of the rays that seemed greater than would have been expected and she raised the question whether there might be some difference in the velocities with which they quit the radio-active substance. To determine this, she let the rays from polonium pass through two slits parallel to each other and 4 cm. apart. A magnetic field of 10,000 gausses acted at right angles to the path of the rays. The rays were received upon a photographic plate. Exposures were made without the magnetic field and again with the field deviating the rays, and the two impressions were compared. She concludes, "There is no indication of differences in the initial velocities of α-rays from polonium." G. F. S.

Joining the Infra-red and Electric-wave Spectra. E. F. NICHOLS and J. D. TEAR. (*Astrophys. J.*, Jan., 1925.)—"This paper was being orally presented by Prof. Ernest Fox Nichols at the meeting of the National Academy of Sciences on April 29, 1924, when his death occurred on the platform of the auditorium."

For decades the gap between the longest ultra-red waves and the shortest electrical waves has been closing up. Long ago Lebedew succeeded in producing electric waves of wave-length 3 mm. In the present paper for the production of electrical waves tiny oscillators consisting of cylindrical tungsten electrodes sealed in glass were used, and the spark for the most rapid oscillations was only a few thousandths of a mm. in length. The radiation thus originated was reflected from an echelon or from another type of interferometer and fell on a radiometer containing elements for the reception of long-wave radiation and its conversion into heat. "Fundamental wave-lengths were obtained as short as 0.9 mm." By the suppression of the fundamental harmonics were noted of wave-length .22 mm. On the other hand, "The infra-red spectrum of the quartz-mercury arc was extended to .420 mm." It is thus seen that the electric-wave spectrum and the infra-red range have been brought to overlap through an octave. G. F. S.

CURRENT TOPICS.

A Suggestion as to the Structure of Light. SIR J. J. THOMSON. (*Phil. Mag.*, Oct., 1924.)—"One of the most interesting facts in the history of the physical sciences is the contradiction between the evidence as to the nature of light afforded by its optical properties on one side and its electrical ones on the other. There has perhaps never been a case where the agreement between the predictions of theory and the results of the most searching and accurate experiments has been so complete as in the undulatory theory of light—a theory which supposes that the disturbance which constitutes light is represented by a continuous function of the time and spatial coördinates and that the energy is distributed continuously throughout the beam. On the other hand, when we consider the electrical properties of light, everything points to great concentration of energy at discrete centres, and that 'the front of a wave instead of being, as it were, uniformly illuminated, is represented by a series of bright specks on a dark ground.' The electrical properties point just as clearly to something resembling the Newtonian corpuscular theory as the optical ones do to the undulatory theory."

The possibility of reconciling the corpuscular or quantum theory of light with the undulatory conception has engaged the thought of the Duc de Broglie in France and of H. A. Lorentz in Holland, and some mention of their work has already been made in this JOURNAL. The necessity for a reconciliation has grown even more imperative by reason of the definitive establishment at the recent Washington meeting of the American Physical Society of the famous Compton effect in the scattering of X-rays.

The Master of Trinity presents a mental picture of the structure "which," says he, "I have found useful in reconciling the optics with the electricity."

The mutual potential energy of an electron and a positive charge is in the tube of electrical force stretching from the positive charge to the negative charge on the electron. If the electron approaches the positive charge, the mutual potential energy is lessened by the quantity of energy contained in the portion of the tube that lies between the first and the second positions of the electron. The tube of force he pictures, not as contracting when the electron comes toward the attracting positive charge, but as drawn out, so that, at the arrival of the electron to its second position, it reaches from the positive to the first position of the electron and thence back to the second position. There is thus a looped tube between the two positions of the electron. This loop gets detached and goes off as a closed ring that soon becomes circular in contour. It travels with the velocity of light in a direction perpendicular to its plane like a circular vortex ring.

The energy of this ring suffers no change so long as the ring itself remains unbroken. "The emission of this ring is taken to represent the emission of radiation, and the energy of the light is concentrated in this ring." Suppose that this travelling ring of force come across a tube of force joining an electron to a positive charge. If the orientation is favorable, the two may coalesce, by the tube at rest annexing the moving tube as a sidewise bend or loop, that may be straightened out by the electron pulling it straight in moving away from the attracting positive charge. Such a change of arrangement would be authorized by the additional energy brought by the moving ring. "If this energy is large enough to detach the electron, a free electron is produced and the ring disappears." If the energy were not sufficient to carry the electron entirely out of the range of the charge, it might suffice to move the electron into a new position of equilibrium. "Thus, suppose the electron were one in the second shell of electrons counting from the outside, there would be a position of equilibrium in the outer layer, and the energy of the ring would be spent in moving the electron from the second shell to the first, the ring would be destroyed, and there would be an absorption of energy. After a time the electron would fall from the first shell to the second, and emit the characteristic radiation by the processes" previously described. "If, however, the energy in the ring were not sufficient to move the electron into a new position of equilibrium, then, though the absorption of the ring would make the electron start away from *P* (the positive charge), the forces acting upon it would soon stop it, and the motion would be reversed and the tube retrace its steps; the ring would be reformed and break away from the molecule against which it struck, and in this case there would be no absorption. Thus we see that the death of a ring means either the birth of a high-speed electron or the emission of a unit of characteristic radiation. This is in exact accordance with the exceedingly interesting and suggestive result obtained by Barkla, that when a beam of Röntgen-rays is wholly absorbed in a gas without the emission of characteristic radiation, the number of high-speed electrons produced is independent of the kind of gas and its physical condition. The rings are the centres in which the energy of light or Röntgen-rays is concentrated. Any transference of energy from light to matter involves the destruction of these rings; thus the amount of energy transferred from a beam of monochromatic light or homogeneous Röntgen radiation must be an integral multiple of a unit." Thus does Sir J. J. Thomson explain the quanta. How does he account for the light-waves?

"At the time the ring is emitted from the atom, and indeed for some time before and after, the electric field in the atom is changing rapidly. This change will produce vibrations in the ring and give rise to electrical waves, so that before and after the ejection of the ring, electric waves are coming out of the atom; as these, like the ring, travel with the velocity of light, the ring will be the centre of a system of waves of the normal type, and predominant among these

are those which have the same periodicity as the vibrations of the ring. The energy in these waves will be small compared with that in the ring."

The author considers the diffraction of his hypothetical light, made up of an army corps of rings surrounded by a cloud of classical light-waves as skirmishers, and concludes: "Thus on these assumptions the diffraction patterns will be the same when the energy of the light is concentrated in a ring as when it is, as in the ordinary theory, spread throughout the whole of the wave." It should be kept in mind that each ring has its own train of attendant waves.

According to Planck's Law the energy in a quantum of any definite type of homogeneous radiation is directly proportional to the frequency of such radiation. From considerations of the energy relations of the ring exactly the same proportionality is deduced, and even a value of Planck's constant is derived that agrees well with the results of determinations made otherwise, though the derivation rests on an assumption for which no justification is presented.

"Absorption of light on this view involves the rupture of the rings forming the cores; the endless ring has to be broken and, as its ends cannot be free, they must join on to another tube of force connecting electrons and positive charges, the energy in the ring being communicated to the carriers of those charges. We have seen that for the ring to be permanently destroyed, the energy in the ring must be sufficient to produce some quasi-permanent change in the molecule, such as the ejection of an electron, or the movement of an electron from one position of equilibrium to another; if no such change is possible, the substance cannot take any energy from the light, and so will be quite transparent." Resonance is attributed to orientation of the tubes of force joined to the electrons, and "the waves preceding the ring having the same period as this electron will have a great effect upon it and will make the tube of force attached to it tend to point in a definite direction. Thus, when the ring strikes the electron, the tube of force attached to the electron, instead of being as likely to point in one direction as in any other, will be concentrated along a definite direction, so that the probability of the rupture of the ring will not be the same as when there is no resonance." From data coming from R. W. Wood's experiments on resonance, the author calculates the radius of a quantum ring for the mercury line 2536 Å. to be much larger than 10^{-8} cm., longer, that is, than for an atom.

"It is possible to imagine electric waves without a ring; thus, if an electron is moving with uniform velocity round the circumference of a circle with a positive charge at its centre, electric waves whose frequency is that of the electron will be generated, but will not necessarily be accompanied by a ring." G. F. S.

Variation with Temperature of the Intensity of Reflection of X-rays from Quartz and Its Bearing on the Crystal Structure. R. E. GIBBS. (*Proc. Roy. Soc.*, A 743.)—Since the publication of

Sir William Bragg's first work on the structure of quartz crystals others have followed in the path he blazed until at present considerable information has been accumulated. All the details of the arrangement of the constituent atoms, however, are not known, though it is established that three molecules are associated with the unit cell, the dimensions of which Bragg has determined. Perpendicular to the axis of trigonal symmetry there is a series of planes which contain silicon atoms alone and oxygen atoms only. The sequence of planes is Si-O-O-Si-O-O, etc. The distance from one silicon plane to the next is known to be 1.79 Å. U., but the distance from an oxygen plane to the nearest silicon plane has not been fixed. When a monochromatic X-ray is reflected from this series of parallel planes, the intensity of the reflected radiation is affected by the difference in phase between the parts reflected from the oxygen planes and from the silicon planes. From the observations in the first, second and third orders of the reflected spectrum, it has been calculated that a distance between these two kinds of planes equal to .63 Å. U. would account for the distribution of intensities actually found. "As a very small change in *d* (the distance between planes of different composition) materially alters the calculated values of the intensity ratios, the slight change in the relative position of the silicon and oxygen atoms which may be expected to occur as the temperature is raised, especially because at about 575° C. quartz passes over to a second structural form, ought to show in the intensities of the basal plane reflections. It was partly for the purpose of testing this expectation, as well as in order to obtain any further information that the experiments now described were undertaken."

The K_α line of molybdenum was reflected from the 111 plane of a quartz crystal placed in an electric furnace. As the temperature rose from 0° to 575° C., the intensity of the light reflected in the first order spectrum slowly decreased, but at the latter temperature it began to fall off rapidly and at 675° was only one-third as great as at 575°. In the second order spectrum at 590° there was a high and sharply marked maximum of reflection. The intensity changes in both orders of spectra are explicable, if the distance from oxygen to silicon plane gradually increases as the temperature rises, at 0° being .635 Å. U. and at 575° becoming .66 Å. U. These reflection experiments confirm the occurrence of some change in quartz at about 575°. Others have shown that its type of symmetry then becomes different. The refractive index, the coefficient of expansion and the specific heat also distinguish this temperature as a point of change.

G. F. S.

The Measurement of the Ratio of the Specific Heats Using Small Volumes of Gas. J. H. BRINKWORTH. (*Proc. Roy. Soc.*, A 743.)—Not every scientific paper contains the announcement of entirely new things. Many recount the results of careful cultivation

applied to already well-tilled fields of research. A long time ago Clément and Désormes showed how to get the ratio of the specific heat of a gas at constant pressure to that at constant volume by studying the drop of pressure consequent upon the adiabatic expansion of the gas. It has been customary to use in this work huge volumes of gas reaching up to 130 litres. That veteran of calorimetric measurement, H. L. Callendar, suggested that much smaller volumes could be employed and proved his contention by the results of his experiments. In the paper under review volumes of gas ranging from 700 c.c. down to 35 c.c. are used. It can readily be understood that the small size of the containing vessels greatly facilitated the carrying out of expansions in the vicinity of −180° C.

Temperatures were got from a resistance thermometer consisting chiefly of 6 cm. of platinum wire .025 mm. in diameter. When air at 155.231° abs. expanded from a pressure of 80.87 cm. of mercury to 75.98 cm., the temperature fell to 152.552°. The final values for the ratio of the two specific heats for air are 1.4032, 1.4077 and 1.4154 for the respective temperatures of 17°, −78° and −118° C. For hydrogen at 17°, −78°, −118° and −183° C., the ratios are 1.4070, 1.4427, 1.4800 and 1.6054. It will be noted that the rate of increase of the ratio with fall of temperature is much more rapid for hydrogen than for air.

From the ratio of the specific heats it is possible to compute the specific heat at constant pressure. For air this is .2395 at 290° abs., .2396 at 195° and .2391 at 155°. For hydrogen at 290°, 195°, 155° and 90°, the values are 3.405, 3.212, 3.041 and 2.628. These values for hydrogen are in close agreement with direct measurements of the same quantity made by Scheel and Heuse. Since the method in the hands of Mr. Brinkworth has shown itself capable of yielding such excellent results for air and hydrogen, it is good to learn that he will apply it to other gases. G. F. S.

The Production of Chlorine by Action of Hydrochloric Acid on Chlorates.—This reaction has long been used for the quick preparation of small amounts of chlorine for tests, but as chlorine oxides are also formed in notable amount, which are unstable and rather violently explosive, the process has been considered inapplicable on the large scale. E. DUFILHO, however, presents a detailed account of a modified process which is safe, in the *Bull. d. Trav. d. l. Soc. d. Pharm. d. Bord.* (1925, **63**, 41). After noting the danger of the unmodified process, Dufilho states that all the chlorine oxides are decomposed at temperatures below 95° C., and he devised apparatus by which the reacting liquids can be kept at the safe temperature, by which the chlorine oxides are decomposed as fast as formed and, therefore, cannot accumulate in sufficient quantity to do harm. That the explosion of a considerable amount of these can be serious was shown in a preliminary experiment in which a solution of sodium chlorate was allowed to flow, drop by drop, into hydrochloric acid,

and the evolved chlorine dehydrated by passing through strong sulphuric acid. The heat evolved by the absorption of water caused an explosion which destroyed the apparatus and even broke some of the laboratory windows. In addition to the regulation of temperature the reaction must be carried out constantly in the presence of excess of acid. The author of the article states that the process has not heretofore been published, but was used on the large scale in the preparation of pure chlorine in connection with the French Chemical Warfare Service. He gives details of the construction of the apparatus used. He also gives data in regard to a modification by which a mixture of sodium chloride and sulphuric acid is used instead of hydrochloric acid itself. Sodium chlorate is used instead of the potassium salt on account of the much greater solubility of the former. It seems, however, that the process can hardly compete in cost and convenience with the processes generally used for the production of chlorine on the large scale. H. L.

Experiments on the Distortion of Single-crystal Test-pieces of Aluminum. H. C. H. CARPENTER and MISS C. F. ELAM, Armourers' and Braziers' Company Research Fellow. (*Proc. Roy. Soc.*, A 742.)—Within the past few years the application of X-rays to the study of crystal structure, associated with the ability to produce single crystals of great size, has made possible investigations in the anatomy and pathology of metallic aggregates that are likely to prove of great practical value.

"When aluminum test-pieces are broken in tension, and subsequently heated to a sufficiently high temperature, they recrystallize and break up into a number of smaller crystals, whose size depends on the amount of distortion." Crystals of the same metal were stretched and then for 16 hours heated to 550° C. It was found that, so long as the extension did not exceed 7 per cent., no recrystallization followed the heat treatment, but that for more than 7 per cent. such rearrangement did occur. Whether a single crystal with axes in new directions or several crystals formed depended on the amount of strain. "Heating does not remove the whole of the hardness acquired through mechanical strain unless the metal recrystallizes. The proportional increase in hardening is greatest during the early stages of extension, but in the case of single crystals a stage is reached when the increase in hardness is approximately proportional to the amount of plastic deformation." Polycrystalline aluminum requires about twice as much force to produce a given percentage of elongation as does a single crystal. One crystal was lengthened by 94 per cent. before it broke under a load of seven tons per square inch. G. F. S.

The Vision of Nocturnal Animals. S. RUSS. (*Nature*, Feb. 28, 1925.)—In examining the conditions under which animals see at night it became of interest to find to what extent the media of the eye absorb radiation before it reaches the retina. A small part of

the retina of an enucleated eye was cut away and a thin plate of quartz closed the opening. Light from a cadmium or a tungsten arc entered the front of the eye and, after making its exit through the quartz, was spread into a spectrum which was photographed. The spectrum from a human eye stops well short of the limits of the ultra-violet. The eye of a lioness, on the other hand, transmitted light over a greater range. It began a little farther toward the red end of the spectrum than the light emerging from the human eye and contained radiation in the ultra-violet down to about wave-length 3400 Å. U. The spectrum of the light coming through the eye of a bear was more limited at both ends than the lioness spectrum, though it contained a short part of the ultra-violet. The eye of a great eagle owl gave the greatest range of all animals examined. It reached from a point in the visible spectrum farther from the infra-red than for any other eye tested to wave-length 3200 in the ultra-violet. A tiger eye gave about the same range as the eye of the lioness, except that it showed a single line well toward the red end of the spectrum. Three human eyes furnished concordant results. "How far the different degrees of transparency shown are dependent on post-mortem changes, it is scarcely possible to say; it may be mentioned, however, that the human specimens were probably fresher than any of the others, yet they showed the greatest opacity to short wave-lengths." The lens of the eye was found to absorb more light than the cornea. It is suggested that the transparency of the eye of an animal to ultra-violet light may have something to do with its ability to see at night. G. F. S.

George Washington as a Chemist.—C. A. BROWNE, Chief of the U. S. Bureau of Chemistry (*Jour. Chem. Education*, 1925, ii, 99–101), calls attention to an experiment upon the production of marsh gas made by George Washington on the evening of November 5, 1783, while in command of the Continental Army. The episode is described by Thomas Paine, the noted pamphleteer, in his treatise entitled, "Of the Cause of Yellow Fever and the Means of Preventing It in Places Not Yet Infected with It: Addressed to the Board of Health in America."

The experiment was made on the creek or river at Rocky Hill, New Jersey. Washington, General Lincoln, Colonel Cob, Paine and several soldiers went aboard a scow. Washington was at one end, Paine at the other end of the scow. Each held a lighted roll of cartridge paper two or three inches above the surface of the water while the soldiers disturbed the bottom of the river with poles. Air (gas) bubbles rose fast, and took fire from the light. The flame descended from the light to the surface of the water. This phenomenon of "setting the river on fire," as it was designated by the country people, was ignition of the "inflammable air" that rose from decomposing vegetable matter in the mud at the bottom of the river.

Paine also describes an experiment which he and Rittenhouse, of Philadelphia, performed, obtaining the same inflammable air by destructive distillation of sawdust. J. S. H.

Determination of the Quantity of an Element in Mixtures and Compounds by X-ray Analysis. R. GLOCKER and W. FROHNMAYER. (*Ann. der Phys.*, 1925, No. 4.)—A beam of X-rays from a commercial Coolidge tube fell upon a crystal of rock salt mounted on the table of Seeman spectrograph, and thence, after reflection, made its way to a recording photographic plate. In the path of the beam, either before or after it reached the crystal, was placed the substance under examination. Such materials as glass and sheet metal were tested without change. Weakly absorbing substances were examined in the form of powder, while strong absorbers were, if possible, brought into aqueous solution and taken up by filter paper. The blackening of the plate was measured photometrically and from a study of the effect of introducing into the path of the rays the material investigated, it was possible to derive the amount of an element in the material. By this process a certain glass was calculated to have 5.45 per cent. barium, whereas chemical analysis showed it actually to have 5.8 per cent. When an attempt was made to analyze a solution containing elements close together in their atomic numbers the results were not good. More satisfactory proved the method of using powders instead of solutions. The presence of impurities, especially of elements close in atomic number to those whose quantity it is desired to determine, render the results much less accurate. G. F. S.

The Absorption of Fluorescent Light in the Emitting Substance. T. DUSENBERG. (*Physik. Zeit.*, Feb. 1, 1925.)—Light from an arc went vertically downward into a fluorescing solution in a glass cell. A beam of the fluorescent light developed in the solution passes out horizontally. Part of it traverses a further length of the solution, while another part makes its way through the solvent alone. The finally emergent beams are studied with a photometer. In the spectrum of the fluorescent light the intensity has in general several maximum values. It is found that of the light at each such maximum the fraction getting through the solution is greater than for light of neighboring wave-lengths. Moreover it appears that, when light produced by fluorescence is later absorbed in a fluorescing solution, it there produces fluorescence. In this as well as in the case of fluorescence due to the absorption of ordinary light, the wave-length of the fluorescent light is greater than that of the light absorbed. Thus is explained the fact that the wave-length of maximum intensity in the light that emerges from a fluorescent solution moves out toward the red as the depth of the solution increases. The shorter waves are more and more completely absorbed and converted into longer waves. G. F. S.

Production of Metallic Magnesium from Fused Salt.—A communication on this subject was presented at the Forty-seventh General Meeting of the American Electrochemical Society held at Niagara Falls, April 23, 24 and 25, 1925. The paper was by W. G. Harvey, of the American Magnesium Corporation at Niagara Falls.

The liberation of magnesium from its chloride by electricity goes back to about 1850 when Bunsen prepared the metal by the electrolysis of magnesium chloride. This process became commercially practicable first in Germany and then elsewhere. The raw material was the hydrated chloride which, having a tendency to decompose into an oxichloride when heated, was mixed with about equal weight of sodium chloride which prevents the decomposition. The mixture melts at about 620° C. The author of the paper described the furnace which he has used in examining this method. A cast steel pot constitutes the cathode and also the electrolytic vessel. The anode is a graphite rod 15 cm. in diameter and 60 cm. long, suspended centrally in the mass with a means for adjusting its height. By this means the constantly lowering bath level can be followed and a constant voltage maintained. After twenty-four hours the material is removed and a new charge added in a molten condition. The rejected mass consists of about 10 per cent. of magnesium chloride and about 80 per cent. of sodium chloride. By holding the concentration within the limits thus indicated practically no sodium is set free. There are some practical objections to this method, especially the intermittent nature of the operation.

The disadvantages of the chloride process determined an investigation as to the electrolysis of the oxide and after considerable experience a type of furnace was devised which is now in use, the anodes located in the centre, and the cathodes toward the side of the furnace. The shell proper consists of a steel box reinforced to prevent warping and change of shape. Carbon anodes are used. The furnace shells are not artificially lined, but a heavy layer of the material solidifies soon after the starting and serves this purpose. Magnesium does not alloy with iron or steel. The bottoms of the castings are water-cooled in order to insure complete solidification at proper points. Further details are given in the original paper. The electrolyte consists of magnesium and barium fluorides in about equal parts with sufficient sodium chlorides to secure the proper fluidity. The barium compound increases the specific gravity of the bath to such a point that the reduced metal rises quickly to the surface and at the same time prevents too rapid settling of the raw material, magnesium oxide. No electrolyte has been found that is lighter than fused magnesium, therefore it is not possible to operate by causing this metal to sink. It is best under these circumstances to have it rise as quickly as possible. Magnesium oxide of a good grade is used as a material and may be obtained in large quantity by the calcination of magnesite.

The commercial properties of magnesium are influenced to a larger

extent by the presence of impurities than those of any other metal. All of these are not necessarily injurious, for the presence of some actually adds desirable properties. Judged from the standpoint of maximum purity, however, all are foreign elements and must be removed, even if, in the manufacture of alloy, they be afterwards added. The furnace product is therefore subjected to a purification process, which yields a refined metal with a minimum magnesium content of 99.9 per cent. H. L.

"Engineman" or "Engineer."—The United States Civil Service Commission has adopted the use of the term "engineman" in lieu of "engineer" in advertising examinations for positions, the duties of which are the operation, maintenance, and repair of stationary or moving engines, the performance of which does not require a professional education.

In reaching a decision as to the adoption of this usage the Commission wrote to classification experts, engineering societies, and individual personnel men. The opinion was unanimous that the term "engineman" was more suitable and less susceptible to confusion than any other term which might be used.—(*Mechanical Engineering*, April, 1925, 303.)

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